AN OVERVIEW OF THE APPLICATION OF STOCK IDENTIFICATION METHODS IN THE MANAGEMENT OF ALASKAN SALMON FISHERIES

Presented at

International Symposium on Pacific Salmon
September 11 - 15, Yuzno Sakhalinsk, U.S.S.R.

by

Douglas M. Eggers

Regional Information Report[1] No. 5J89-08

Alaska Department of Fish and Game
Division of Commercial Fisheries
Juneau, Alaska

September 1989

---

[1]The Regional Information Report Series was established in 1987 to provide an information access system for all unpublished divisional reports. These reports frequently serve diverse ad hoc informational purposes or archive basic uninterpreted data. To accommodate timely reporting of recently collected information, reports in this series undergo only limited internal review and may contain preliminary data; this information may be subsequently finalized and published in the formal literature. Consequently, these reports should not be cited without prior approval of the author or the Division of Commercial Fisheries.

TABLE OF CONTENTS

Page

LIST OF FIGURES ii

INTRODUCTION. 1

METHODS 2

RESULTS AND DISCUSSION. 3

Scale Pattern Analysis in Sockeye Salmon Mixed Stocks Fisheries . 3

Bristol Bay 3
North Alaska Peninsula. 5
Chignik 6
Olga/Moser Bay, Kodiak. 7
Upper Cook Inlet. 7
Copper - Bering River 8
Lynn Canal. 9
Taku - Snettisham 10
Sumner Strait - Stikine River 10

Yukon River Chinook Salmon Fisheries. 12

South Alaska Peninsula June Fishery 13

Prince William Sound Pink Salmon Fishery. 16

LITERATURE CITED. 18

FIGURES 21

LIST OF FIGURES

Figure | Page

1. Location of study areas in Alaska and western Canada: (1) Bristol Bay, (2) North Alaska Peninsula, (3) Chignik, (4) Olga - Moser Bay, Kodiak Island, (5) Upper Cook Inlet, (6) Copper - Bering Rivers, (7) Lynn Canal, (8) Taku - Snettisham, and (9) Sumner Strait - Stikine River. Figure modified from Marshall et al. (1987) 21

2. Bristol Bay sockeye salmon river systems, fishing districts, and sampling programs of the Bristol Bay management system 22

3. Total inshore run (catch + escapement) of sockeye salmon to the Kvichak River, 1956-1989 23

4. Fishing effort (thousands of boat days) for Nushagak, Naknek/Kvichak, Egegik, and Ugashik fishing districts, 1967 - 1987 24

5. (A) Deviation by brood year from pooled eastside river systems return per spawner, for pooled river systems terminating in the Naknek/Kvichak District, and (B) for pooled river systems terminating in the Egegik/Ugashik District 25

6. Estimates of stock composition, in terms of river of origin, for the total catch of sockeye salmon in the Naknek/Kvichak, Egegik, and Ugashik Districts for 1986-1988. Relative area of pie charts scaled to relative catch magnitude for respective district and year 26

7. Difference between estimated return based on assigning district catches to river systems terminating in the respective district and return based on allocation of district catches to river of origin based on scale pattern analysis, 1986 - 1987. 27

8. Stock composition of catches of sockeye salmon from Ugashik District catches through time, 1986 - 1988. 28

9. Harbor Point to Cape Seniavin area (A) and Cape Seniavin to Strogonof Point area (B) of the Northern District, North Alaska Peninsula Fishery Unit. Also shown are the drainages of the four principal sockeye salmon stocks (Nelson Lagoon, Bear River, Sandy River, and Ilnik Lagoon). 29

LIST OF FIGURES (Continued)

		Page
10.	Stock composition, in terms of fish originating in Bristol Bay river systems and North Peninsula river systems, of sockeye salmon catches North Peninsula fisheries. Catches from A. the Cape Seniavin to Strogonof Point area, and B. the Harbor Point to Cape Seniavin area	30
11.	The Chignik and Black Lakes area showing the location of the fishery and the major sockeye salmon spawning drainages. Figure modified from Marshall et al. (1987).	31
12.	Earliest, latest, and computed average time-of-entry curves from the Chignik sockeye salmon runs based on adult tagging conducted from 1962 - 1966 (frame A); and daily stock composition estimated by SPA for the years 1978-1984 (frame B). Both frames refer to the same run. Figure taken from Marshall et al. (1987)	32
13.	Moser-Olga Bay Section, Cape Alitak Section, and Deadman-Portage Bay Section of the Alitak Bay District, Kodiak Island Fishery Unit. Also shown are drainages of the three principal sockeye salmon stocks (Upper Station Lakes, Akalura Lake, and Fraser Lake)	33
14.	The upper Cook Inlet area showing the location of the fisheries and major spawning drainages sockeye salmon. Setnet fisheries are (1) Salamatof Beach, (2) Kalifonski Beach, (3) Cohoe/Ninilchik Beach, (4) West-side, and (5) Kalgin. The driftnet fishery operates in the Central District. Figure taken from Marshall et al. (1987) . .	34
15.	Cumulative proportion of catch-per-unit-of-effort in the drift fishery of age 1.3 sockeye salmon bound for the Kenai, Kasilof, and Susitna Rivers 1979-1981. Boat-days is the unit of effort. Figure taken from Marshall et al. (1987)	35
16.	The Copper-Bering Rivers area showing the locations of the fisheries and major sockeye salmon spawning drainages. Channels of the Copper River Delta fishing District (212-10 through 212-30) and (1) Egg Island, (2) Pete Dahl, (3) Kokinhenik, and (4) Softuk. Figure taken from Marshall et al. (1987)	36
17.	Catch-per-unit-of-effort of Upriver and Delta origin of salmon aged 1.3 in the Copper River district fishery during 1982. Boat days are unit of effort. Figure taken from Marshall et al. (1987) . . .	37
18.	The Lynn Canal area showing the location of the fishery and the major sockeye salmon spawning drainages. Figure taken from Marshall et al. (1987)	38
19.	Catches of sockeye salmon in the Lynn Canal fishery, 1976-1989 . .	39

LIST OF FIGURES (Continued)

Page

20. Representative scales from sockeye salmon, ages 2.1, 2.2, and 2.3 taken from the Chilkoot Lake and Chilkat Lake spawning areas . . . 40

21. Run timing through the Lynn Canal fishery averaged over the years 1981-1988, for Chilkoot, early Chilkat, and late Chilkat sockeye salmon stocks. 41

22. Run magnitude (catch + escapement) of sockeye salmon in Lynn Canal, 1976-1989. 42

23. The Taku - Snettisham area showing the major spawning drainages for sockeye salmon in the Taku River (Kuthai Lake, Little Trapper Lake, Tatsamenie Lake, and the mainstem Taku River) and Snettisham area (Speel Lake and Cresent Lake). Figure taken from Marshall et al. (1987). 43

24. Estimates of the percent contributions of age 1.3 and 1.2 Taku River stock groupings to the traditional District 111 fishery, Canyon Island fishwheel catches, and the Canadian Taku River fishery, 1986. Figure taken from McGregor and Walls (1987) 44

25. District 111 gillnet fishing area, with subdistricts. Shaded area represents the portion of the district open in the supplemental fishery. Figure taken from McGregor and Walls (1987) 45

26. The transboundary Stikine River, major tributaries, and the fishery areas (District 106, District 108, and Canadian inriver fishery area). Figure taken from Jensen and Frank (1987) 46

27. Major sockeye salmon spawning drainages in the northern boundary area. Stock groupings include Alaska coastal lakes, Nass and Skeena River, and Stikine River 47

28. Stock composition, in terms of fish originating in Stikine River, Alaska coastal lakes, and Nass - Skeena River, of catches of sockeye salmon from District 106, 1982 - 1988. Data taken from Oliver (1988) 48

29. Migratory timing of the Tahltan and Stikine sockeye stock groups as indicated by the weekly proportion of total stock group CPUE in the Stikine River test fishery, 1987. Figure taken from Jensen and Frank (1987). 49

30. Alaskan portion of the Yukon River drainage showing the six regulatory districts and the major spawning tributaries for the lower and middle runs of chinook salmon. Figure taken from Brannian (1989) 50

LIST OF FIGURES (Continued)

Page

31. Canadian portion of the Yukon River drainage showing the major spawning tributaries for the upper run of chinook salmon. Figure taken from Brannian (1989) 51

32. Reconstruction of the run (catches in the lower, middle and upper river fishing areas and escapement) for the lower, middle, and upper river stocks of chinook salmon in the Yukon River. Relative area of pie charts scaled to relative catch magnitude for respective area of the river and year. Data taken from Brannian (1989) 52

33. Cumulative proportions of chinook salmon CPUE by date and run (lower, middle, and upper) for the lower Yukon River test fishery for 1982 (top panel) and 1983 (bottom panel). Figure taken from Brannian (1989) 53

34. Fishery unit definitions by which 1987 tag recoveries, catches and escapements were reported for western and central Alaska salmon fisheries. Figure taken from Eggers et al. (1989) 54

35. Tagging locations in the Unimak and Shumagin Islands area used during the South Peninsula tagging study, 1987. Figure taken from Eggers et al. (1989) 55

36. Timing of 1987, tag releases and catches of sockeye and chum salmon in the combined Unimak and Shumagin District. Figure taken from Eggers et al. (1989). 56

37. Stock composition (% of total return) of western and central Alaska sockeye returns versus stock composition (% of surviving releases) of Unimak releases of sockeye salmon, for various fishery units. Figure taken from Eggers et al. (1989) 57

38. Stock composition (% of total return) of western and central Alaska chum returns versus stock composition (% of surviving releases less estimated Asian stocks) of Unimak releases of chum salmon, for various fishery units. Figure taken from Eggers et al. (1989) 58

39. The Prince William Sound area with fishing district boundary lines and locations of hatchery facilities 59

40. Hatchery and wild stock composition of 1987 Prince William Sound pink salmon catches for Eastern and Southeastern Districts; Northern, Northwestern, and Coghill Districts; and Southwestern District. Relative area of pie charts scaled to relative catch magnitude for respective district groups 60

INTRODUCTION

Management of Pacific salmon (*Oncorhynchus*) fisheries is an active process of conservation of the stocks and allocation of catches among competing user groups. Management objectives are established to fulfill the economic, social, and legal demands of the public within the biological constraints of the resource. The dual responsibility of the fisheries manager, to conserve and to allocate, has been the impetus for development and implementation of new techniques of stock assessment. The information provided in new stock assessment techniques enable fisheries managers to evaluate, quantitatively, management performance in meeting the dual objectives of conservation and allocation. A key innovation in the development of new stock assessment techniques has been the implementation of various stock identification methods as routine (i.e., information, such as enumeration of catch and escapement, that is collected on an annual basis) fisheries management practices.

Stock identification methods are used to estimate stock-specific and age-specific catch in mixed stock fisheries. This information, when combined with age-specific and stock-specific estimates of escapement, result in stock-specific estimates of total return. This information can result in more accurate forecasts (both in-season and pre-season) of run strength and estimates of optimal escapement goals. In situations where stock-specific catches are stratified by space and time, managers are often able to implement stock-specific harvest strategies. With stock specific harvest strategies, managers are more consistent in achieving escapement goals and provide for conservation of the stocks during periods of low abundance and for higher average sustained harvest levels. Finally, knowledge of stock-specific catches, enables the political resolution of the allocation issues. Finally, negotiated equity arrangements in conjunction with stock specific harvest strategies, enable harvestable surpluses to be shared among competing user groups through the implementation of specific management measures.

This paper reviews the major application of stock identification methods that are used in the management of Alaskan salmon fisheries. Four applications are reviewed. 1. Scale pattern analysis (SPA) is routinely used in the management of terminal harvest sockeye salmon fisheries on mixed stocks from river systems that collectively terminate in the fishing area. The nine cases, (Bristol Bay, North Peninsula, Chignik, Kodiak, Upper Cook Inlet, Copper - Bering River, Lynn Canal, Taku - Snettisham, and the Sumner Strait - Stikine River) where SPA is used in Alaska sockeye salmon fisheries management are reviewed. 2. SPA is used to apportion catches of chinook salmon in Yukon River fisheries to lower, middle and upriver stocks. The apportioned catches together with estimates of upriver escapement tagging is used to determine stock-specific rates of exploitation in fisheries throughout the Yukon drainage. 3. A massive tagging study was conducted in 1987 to estimate the stock composition of sockeye and chum salmon catches in the interception fishery that occurs in June in the vicinity of Unimak and Shumagin Islands. 4. Massive coded wire tagging (CWT) is used to determine hatchery and wild stock composition of pink salmon catches in the Prince William Sound purse seine fishery.

METHODS

The objective of stock identification in salmon fisheries management is to determine the stock-specific catches in mixed stocks fisheries. In order to identify the stock of origin of individual fish in the catch, a stock-specific marker must exist in the population exploited by the fishery. These methods fall into two catagories, those using biological markers and those using man-induced physical markers. In the first category, the marker is a pre-existing biological attribute that clusters according to management units or stocks and is sufficiently distinctive to enable the statistically reliable separation of catches into stocks. Distinctive scale patterns of fish from individual or aggregated river systems is an example of a biological marker. In the second catagory, a marker is introduced into the stock by the fishery manager. Here a portion of the stock is captured and physically marked. The number of individuals marked must be large enough to ensure that a statistically meaningful number of recoveries will be found in the catch. Examples of man-induced markers, include the coded wire tag and the numbered spaghetti tag.

There are two phases of a stock identification study using biological markers. The first phase involves searching for an appropriate biological marker. The escapement of each stock that is potentially exploited by the fishery is sampled (i.e., these are referred to "knowns" since the stock of origin of these individuals is known). A number of biological attributes are measured for each individual in the "known" sample. The data from the "known" samples are examined to determine whether differences in the biological attributes exist among the stocks in the "known" samples and whether these attributes cluster in stock or groups of stocks that correspond to management units. If differences exist, then a statistical procedure can be developed to estimate the proportion of stocks in samples of catches. The second phase of the study involves examination of the the catch.

Catches are sampled and, generally, stratified by time and area. The biological attributes of the catch sample are measured in the same manner that biological attributes were measured in the "known" sample. The statistical procedure is then applied to the data from the sample of catches to estimate stock composition.

There are three phases of stock identification studies using man-induced physical markers. The first phase involves placing the markers in the population at some point prior to capture by the fishery. The second involves sampling the catches for presence of marked individuals. The third involves sampling of the "known" (escapement) population for presence of marked individuals to estimate marked to unmarked ratios. To estimate the proportion of each stock which was available to the fishery, the number of marks found in the catch sample is expanded for un-marked individuals of the respective stock present in the catch sample. The expansion is based on the ratio of marked to unmarked individuals in the respective stock of origin.

RESULTS AND DISCUSSION

Scale Pattern Analysis in Sockeye Salmon Mixed Stocks Fisheries

Application of scale pattern analysis to the management of Alaska's sockeye salmon was reviewed, in an earlier paper, by Marshall et al. (1987). The reader is referred to that paper for details of methods and background literature. Nine examples of application of scale pattern analysis are reviewed here (Figure 1). Two of the studies (Taku - Snettisham and Sumner Strait - Stikine River) have been expanded and several new studies (Bristol Bay, North Alaska Peninsula, and Kodiak) have been implemented since the publication of Marshall et al. (1987).

Scale pattern analysis is based on differences in the arrangement of circuli on scales. These patterns are histories of growth. Salmon with similar growth histories have similar scale patterns. In many cases, scale patterns cluster by river system of origin, or by lakes in close proximity and similar climatic regimes. Because these clusters often correspond to management units of stocks, SPA is extremely useful in estimating stock specific catches.

Bristol Bay

The Bristol Bay sockeye salmon fishery is the world's largest. The Bristol Bay sockeye salmon runs are at historical maximum levels, and inshore catches have averaged over 22 million fish since 1979. Runs to 9 river systems are exploited in 5 terminal fishing districts (Figure 2). Both set and drift gillnet gear are used in all Bristol Bay fishing districts. The fishery is managed by time/area closures implemented by emergency order, to achieve fixed escapement goals for individual river systems (Minard and Meacham 1987). An extensive stock assessment program, including enumeration of catch and escapement, and sampling for age composition of catches and escapements has been in place since the early 1950's. Estimates of total return from parent escapement is available for all major river systems. These estimates assume that catches in the terminal fishing districts originate in the river systems terminating in the respective district based on the relative escapement magnitude by age class (see Eggers and Rogers 1987 for background literature).

The Kvichak River system is the largest producer of sockeye salmon, and contributes roughly half of the total Bristol Bay run. The Kvichak River has been a cyclic dominant system, with peak run years occurring on a 4 or 5 year cycle depending on the freshwater age of fish returning from cycle year escapements. Recently, the cyclical pattern of returns has been changing (Eggers and Rogers 1987). These changes have presented an opportunity to alter the pattern of returns to the Kvichak River system, from one very large run every five years, to three or four moderate to large runs out of every five years (Figure 3). A much greater economic value results from the more stable pattern of runs and is preferred over the cyclic pattern of runs by the fishing industry. The Department of Fish and Game has sought to increase off cycle escapement, during the period 1985- 1987, by decreasing the fishing time in the Naknek - Kvichak District.

Because of the altered management strategy for the Kvichak River system and the concomitant increase in runs to the Egegik and Ugashik River systems, there has been a large increase in fishing effort, since 1979, in the Egegik and Ugashik fishing districts (Figure 4). The burden of reduced fishing times in the Naknek/Kvichak District has fallen more heavily on set gillnet fishermen, who cannot fish in other fishing districts because alternative fishing sites in those districts are not available. It is well known from the early tagging work (Pennoyer and Nelson 1967, Straty 1969) that fish which originate in the Kvichak and Naknek Rivers are intercepted to some extent in the Egegik and Ugashik Districts. In addition to the concern by Naknek/Kvichak set gillnet fishermen, there has been concern by all Bristol Bay fishermen over effect of these interceptions on ADF&G's attempts to rebuild the Kvichak off-cycle runs.

With the interceptions of Naknek and Kvichak River fish in other eastside fishing districts, there is potential for errors in catch allocation procedures used to construct the escapement - return data base (Eggers and Rogers 1987). For example, production (i.e., return per spawner) is consistently higher for the Egegik - Ugashik river systems than for the Naknek and Kvichak River systems (Figure 5). Is this higher production due to more favorable rearing habitat in the Egegik and Ugashik River systems or are catches of Naknek and Kvichak fish being consistently and erroneously assigned to the Egegik and Ugashik River systems. There is concern among ADF&G scientist over the accuracy of the escapement - return data base, since these data are being used to develop optimal harvest escapement goals for individual river systems, develop pre-season forecasts of abundance, and develop alternative harvest policies for the Kvichak run.

In response to these public and scientific concerns, ADF&G initiated a stock identification study of eastside (i.e., Naknek/Kvichak, Egegik, and Ugashik Districts) catches based on scale pattern analysis beginning in 1986. Escapement scales of known origin were used to construct a four-way (Kvichak, Naknek, Egegik, and Ugashik) linear discriminant model for the 1.2, 1.3, and 2.3 (European classification, Koo 1962) age classes (Cross and Stratton 1987, 1988, and 1989). Commercial catch scales (samples stratified by district and time) were classified with the discriminant functions to estimate the contribution of each river to the age-1.2, -1.3, and -2.3 harvests. Although stocks originating in river systems terminating in each district dominate the catches of the respective district, significant numbers of interceptions occurred in each of the eastside fishing districts (Figure 6). To examine the potential for errors in historical apportionment of catches to river of origin the district catches were compared to the collective catches of fish that originate in the respective district caught in the three eastside fishing districts (Figure 6). For the three years examined the historical method of apportioning catches to river of origin, consistently under-estimated the catch of Naknek/Kvichak fish and over-estimated the catch of Egegik/Ugashik fish. This result is consistent with the higher return per spawner estimated for Egegik/Ugashik fish based on historical catch apportionment methods (Figure 5).

In attempts to identify potential management measures such as time-area closures, which would reduce the interceptions of Naknek/Kvichak fish in the Egegik and Ugashik districts, stock composition of catches was examined over time in the Ugashik and Egegik Districts as well as areas within the Egegik district. For the Egegik District, no differences in stock composition were found between times and areas within fishing districts (Cross and Stratton 1988). It is not possible with simple time-area closures, to reduce interceptions in the Egegik district without jeopardizing the ability to harvest the Egegik run. For the Ugashik District, stocks originating from outside the Ugashik District were a much higher contribution in the catches early in the season (Figure 8). In subsequent years fishing has been delayed in the Ugashik District to reduce interceptions without under-harvesting the Ugashik run.

North Alaska Peninsula

The sockeye salmon fishery in the Northern District, north Alaska Peninsula, is directed at four stocks of sockeye salmon, Bear River, Sandy River, Nelson Lagoon, and Ilnik Lagoon. Sockeye salmon catches in the Northern District are at historical maximum levels and have averaged 2.6 million fish per year since 1979. The catches come from inside Nelson Lagoon and from the area within 3 miles of the Alaska Peninsula between Strogonof point and Wolf Point which is at the southern entrance to Port Moller (Figure 9). The majority of the sockeye are caught with drift gillnet gear in outside areas, and all sockeye salmon inside Nelson and Ilnik Lagoons are caught with set gillnets.

Because of the proximity of the Northern District to the migratory corridor of Bristol Bay sockeye salmon and the coincidence of recently increased catches in the Northern District with those in the Bristol Bay sockeye fishery, public concern has surfaced over alleged interceptions of Bristol Bay fish in the north Alaska Peninsula sockeye fishery. Earlier tagging studies reviewed by Straty (1975) clearly showed that the migratory pathway of returning Bristol Bay sockeye salmon was well offshore of the Northern District. These studies also showed that no tagged fish from limited releases in the vicinity of Cape Seniavin were recovered in Bristol Bay fisheries. However, in response to continuing public concern over potential interceptions of Bristol Bay salmon and a desire by ADF&G biologists to explore the feasibility of using SPA to estimate stock-specific catches and develop an escapement - return data base for the north Peninsula sockeye salmon stocks, ADF&G initiated a SPA study for the Northern district catches in 1988 (Geiger 1989).

The 1988 catches of sockeye salmon in the Northern District were dominated by age-2.2 and -2.3 fish. Since these age classes were not significant in the Ilnik lagoon and Sandy River escapement samples, it was necessary to include only the Bear River and Nelson Lagoon scales as standards for the north Alaska Peninsula stocks (Geiger 1989). Escapement scales of known origin were used to construct a three-way (Ugashik, Bear River, and Nelson Lagoon) linear discriminant model for the 2.2 and 2.3 age classes. Commercial catch scales (samples stratified by area and time) were classified with the discriminant functions to estimate the contribution of each river to the age-2.2, -2.3 harvests. Results showed that Bristol Bay fish did not occur in the southwestern area (Harbor Point to Cape Seniavin) but were present in substantial numbers (estimated catch of 300 thousand fish) in the more northeastern area catches, Cape Seniavin to Strogonof Point (Figure 10). The high catch of Bristol Bay fish occurred when the Northern District was opened to fishing northeast of Ilnik Lagoon.

A five way (Bear River, Nelson Lagoon, Ugashik River, Egegik River, and Naknek River) linear discriminant model was constructed for the 2.3 age class. This model had marginal classification accuracy, because of the large number of constituent stocks. To examine the possibility of north Alaska Peninsula sockeye stocks being intercepted in the Bristol Bay fishery, the five way model was applied to commercial catch scales from the Ugashik district, which is the Bristol Bay fishing district in closest proximity to the north Alaska Peninsula sockeye stocks. Less than 5 % of the scales from the Ugashik catch was classified to north Alaska Peninsula origin. In view of the relatively poor classification error in the five way model, this result is consistent with the hypothesis that no north Alaska Peninsula sockeye salmon are intercepted in the Ugashik District (Geiger 1989).

Chignik

Catches of Chignik sockeye salmon are at historical maximum levels and have averaged 1.6 million since 1979. The Chignik run of sockeye salmon consists of two stocks. The early run arrives in June and is predominantly age 1. freshwater. This run spawns in the tributaries of Black Lake and rears to varying degrees in Black Lake (Figure 11). The late run arrives in July and is predominantly age 2. freshwater. The late run spawns in the tributaries and along beaches of Chignik Lake and rears in Chignik Lake.

Until 1981 management to achieve separate escapement goals for the early and late run was based on average time of entry curves (Figure 12A). These curves were a composite of tagging studies conducted from 1962 - 1964 which attempts to reconstruct the relative contribution of the two stocks, over time, to the Chignik weir counts (Dahlberg 1968). The average time of entry curve was then used to apportion historical catch and escapement data into the two run components. These data were analyzed to set escapement goals.

Because of the inherent problems with the assumptions used to determine the average time of entry curves based on tagging (Marshall 1987), a scale pattern analysis study was initiated in 1978. The objective of the study was to develop annual estimates of stock specific catches, escapement, and time of entry curves (Conrad 1982). Results of this work demonstrate that considerable year to year variation exist in the time of entry curves (Figure 12B), and that the runs to Black Lake are more variable than the runs to Chignik Lake. Based on the apportionment of catches and Chignik weir counts with average time of entry curve, it is very likely that considerable errors exist in the historical Chignik escapement - return data. A more thorough review of the application of SPA to management of the Chignik sockeye fishery is provided in Marshall et al. (1987).

Olga - Moser Bay, Kodiak Island

The major runs of sockeye salmon to the Alitak Bay District in the Olga-Moser Bay area of Southwestern Kodiak Island (Figure 13) are to Upper Station Lakes and Fraser Lake. Minor runs return to Akalura and Horse Marine Lakes. The sockeye salmon were introduced to Fraser Lake, a formerly barren system, after construction of a fish passage facility in 1951. The Fraser run has increased steadily, with an estimated 1989 run of 1 million fish. With the introduced Fraser run and the rebuilding of the Upper Station and Akalura run, the Alitak Bay District is the most important sockeye producing district in the Kodiak Area.

The Alitak district fisheries use two gear types. Purse seines operate exclusively in the Cape Alitak and Deadman-Portage Bay Sections. The Deadman-Portage Bay section is opened primarily to harvest pink and chum salmon. Set gillnets operate throughout the district and exclusively in the Moser-Olga Bay Section.

It is difficult to control the interception of salmon bound for Moser-Olga Bay systems. Interception occurs at different points along the westside of Kodiak Island in fisheries for other strong runs of sockeye salmon (i.e. Red and Karluk River). Late run components of sockeye runs such as Karluk and Upper Station are coincident with the return of pink salmon. Bycatches of late run sockeye in purse seine fisheries directed at pink salmon, greatly complicate the management of late run sockeye salmon stocks. The strength of a particular run can best be assessed as it reaches terminal fishing areas. If fishing is restricted to terminal areas, the stock can be more easily managed for individual river system escapement goals which can result in maximum sustained yield. In the Olga-Moser Bay area, the strict terminal fishing management option is constrained by the need to maintain traditional fishing areas for the competing gear groups.

A scale pattern analysis study was initiated in 1988 to estimate stock - specific catches in the Alitak Bay District, by area and time (Swanton 1990). The results are preliminary and not yet available. It is anticipated that historical scale collections since 1985 will be analyzed, stock - specific catches estimated, and an escapement - return database developed for the Upper Station and Fraser runs.

Upper Cook Inlet

The major runs of sockeye salmon to upper Cook Inlet occur in the Kenai River, Kasilof River, and Susitna River. Minor runs occur in the Crescent River and Fish Creek (Figure 14). The drift and set gillnet fisheries of upper Cook Inlet (Figure 14) have averaged four million sockeye salmon annually since 1979. Two, 12-h fishing periods are usually permitted each week with more or fewer periods depending on run size. Until recently, the weekly schedule has been adjusted only slightly. Hydro-acoustic technology is used to count escapement into the visually occluded rivers of the upper Cook Inlet region.

Since 1978 scale pattern analysis has been used to estimate the contribution of the major runs to the catches of sockeye salmon in the upper Cook Inlet fishery. With the availability of escapement estimates by river system and stock-specific catches, an escapement - return data base has been developed for the major river systems. Based on this information, ADF&G has developed pre-season forecasts of run strength and established escapement goals for the major river systems of upper Cook Inlet.

Besides a postseason tally of catches by district and run, SPA is used to reveal migratory patterns that can aid managers in targeting fishing effort on specific runs. There is some opportunity to direct fishing effort to specific stocks in the drift gillnet fishery in the Central District. The bulk of the Kasilof River run enters the district before the other major runs (Figure 15). The early components of the upper Cook Inlet fishery are now managed to control exploitation on the Kasilof run. The SPA studies also revealed that a minor stock, Fish Creek, was not being effectively exploited in the existing fishing areas. As a result of this study, the Alaska Board of Fisheries established a new set gillnet fishing area adjacent to the mouth of Fish Creek. A more thorough review of the application of SPA to management of the upper Cook Inlet sockeye fishery is provided in Marshall et al. (1987).

Copper - Bering River.

The catches of sockeye salmon in the drift gillnet fishery have averaged 700 thousand fish annually, since 1979. Catches were presumed to be from stocks that migrate through the Copper River (Upriver stocks) or from several small systems in the Copper River Delta and around the Bering River (Delta stocks). The upriver stocks were presumed to be the only significant source of production for this fishery (Pirtle 1967). In 1978, hydro-acoustic counters were installed on the Copper River at Miles Lake (Figure 16). The fishery has been regulated to attain escapement goals past the Miles Lake sonar site.

The Delta stocks do not migrate past the Miles Lake sonar site. The importance of Delta stocks to the local fishery was demonstrated with SPA studies (Marshall et al. 1987). During the years 1982, 1983, and 1984, the Delta stocks contributed 49%, 48%, and 21%, respectively, of the catches in the Copper-Bering River fisheries. This unexpectedly large numerical and economic contribution of sockeye salmon from the Delta stocks has prompted a broadened management approach. The SPA studies show that the Delta and Upriver stocks are thoroughly mixed in the fishery (Figure 17). However, in-season SPA studies provide weekly estimates of catch by run and catch by age. This information enables managers to protect the Delta stocks at very low stock levels, even in situations of a strong upriver run.

The annual escapement estimates for the Delta stocks are made with aerial surveys and are not accurate enough to develop spawner-recruit data. However, the combined estimates of stock-specific catches and accurate escapement counts at the Miles Lake sonar site do enable the development of spawner-recruit data for the Upriver stocks. ADF&G has developed estimates of optimal escapement goals and a pre-season forecast for the Upriver stocks. A more thorough review of the application of SPA to management of the Copper -Bering River sockeye salmon fishery is provided in Marshall et al. (1987).

Lynn Canal

The catch of sockeye salmon in the drift gillnet fishery in Lynn Canal, Southeast Alaska (Figure 18), has consistently exceeded 300 thousand fish annually since 1983 (Figure 19). These higher catches are due in part to the closing of the Icy Strait entry corridor to the Southeast Alaska purse seine fishery in 1974. This seine fishery is directed at pink salmon and had high bycatches of sockeye salmon when prosecuted in Icy Strait. Since most pink salmon stocks were available to the seine fishery in inside waters, the Icy Strait closure enabled the passage of sockeye without jeopardizing the ability of the seine fishery to harvest pink salmon. After 1974, most harvests of northern Southeast Alaska sockeye stocks occurred in the terminal gillnet fisheries in Lynn Canal and the Taku-Snettisham area where runs could be managed for stock specific escapement goals and maximum sustained yield.

The Lynn Canal gillnet fishery is supported by runs of sockeye salmon to the Chilkat and Chilkoot Rivers. The fishery is managed to achieve specific escapement goals at counting weirs near the outlet of Chilkat and Chilkoot Lakes. The fishery is also managed to achieve weekly catches that are proportional to stock size throughout the run. This management practice was established to protect all segments of the run. Scale pattern analysis studies were implemented in 1981 to provide estimates of stock-specific catches. These data together with fishery performance data and in-season escapement data, enable managers to meet the above objectives (McPherson and Marshall 1986).

The scale patterns from the two stocks are very distinctive (Figure 20). Chilkat Lake is very productive and has a low density of rearing juvenile sockeye since spawning area is limiting for the system. Sockeye that originate in Chilkat have very large freshwater growth zones on their scales reflecting the high freshwater growth rates. Chilkoot Lake is also productive, but a much higher density of rearing juvenile sockeye occur in the lake because of greater amount of spawning habitat available in the Chilkoot system. The freshwater growth rate of Chilkoot is low and is reflected by the relatively small freshwater growth zone on the scales. The scale patterns for the two stocks are so distinctive that stock identification can be done visually.

The SPA studies have shown that timing differences exist between the Chilkoot and Chilkat stocks (Figure 21). The early catches are dominated by Chilkoot fish. The early Chilkat run is present but generally in low abundance. The two stocks also segregate as they migrate into the upper areas of Lynn Canal. The catches from areas near the river mouths are dominated by the respective stock.

With availability of stock-specific catches, an escapement - return data base has been constructed for both Lynn Canal stocks (Figure 22). Optimal escapement goals have been developed, and pre-season forecasts of run strength are being developed for the 1990 fishery and will be incorporated in the annual Alaska salmon forecasts and harvest projections document (Geiger and Savviko 1989).

Taku - Snettisham

The drift gillnet fishery that occurs in District 111, Southeast Alaska Fishery Unit, exploits sockeye salmon that originate in the Taku River and two lake systems (Speel and Crescent Lake) that discharge into Port Snettisham (Figure 23). The spawning and rearing areas for Taku River stocks are in Canada. These include Kuthai Lake, Little Trapper Lake, Tatsamenie Lake and the mainstem Taku River. Additional exploitation on the Taku stocks occurs in the Canadian inriver gillnet fishery. The spawning and rearing area for the Port Snettisham stocks are in the United States.

The treaty between the governments of the United States and Canada (Annex IV, February 1988) concerning Pacific Salmon entitles Canada to harvest 18 % of the total allowable catch (TAC) of sockeye salmon from the Taku River. For the Taku River the TAC is determined as the return in excess of the escapement goal of 71,000 to 80,000 fish. Escapement are estimated by joint U.S. and Canadian mark-recapture study, with tag releases in the lower Taku River at Canyon Island, and subsequent tag recovery in the Canadian areas of the Taku drainage (McGregor and Clark 1987). The sockeye salmon of U.S. origin (i.e. Port Snettisham fish) are caught in District 111 gillnet fishery are not considered in determination of Canadian entitlements. Thus, stock identification of the District 111 catches is necessary. SPA is used to estimate catch by stock for the District 111 drift gillnet fishery in-season so that compliance with the US/Canada treaty can be monitored for District 111 and the Canadian fishery in the Taku River (McGregor and Walls 1987).

Escapement scales of known origin were used to construct a six stock (Kuthai, Little Trapper, Tatsamenie River, mainstem Taku, Speel, and Cresent) linear discriminant model for the 1.2 and 1.3 age classes. Commercial catch scales (samples stratified by district and time) were classified with the discriminant functions to estimate the contribution of each river to the age- 1.2 and -1.3 harvests (McGregor and Walls 1987). The discriminant model was also applied to the sample scales from the Canyon Island fishwheels and the Canadian fishery. There exists substantial differences in the run timing among the stocks of the Taku River (Figure 24).

At present the SPA analyses and escapement estimates are used for aggregate Taku stock in-season management and post-season evaluation of U.S./Canada treaty compliance. In view of the differential run timing among stocks within the Taku drainage, the potential exists to develop stock specific management practices for the District 111 and Canadian inriver fisheries. In addition, differences in the Taku and Port Snettisham contribution to District 111 catches occur in subdistricts within District 111. The southern areas of the District (Figure 25) tend to have a higher Port Snettisham contribution (A. McGregor personal communication), and potential exists for the development of stocks specific management practices for Port Snettisham stocks of sockeye.

Sumner Strait - Stikine River

The District 106 - 108 fishery (Figure 26) exploits a complex mixture of stocks. These include the Stikine River (mainstem Stikine and Tahltan Lake), the Alaska stocks which include 24 small coastal lake systems, and the Nass/Skeena River stocks of Canada (Figure 27).

The treaty between the governments of the United States and Canada (Annex IV February 1988) concerning Pacific Salmon entitles Canadian fishermen to harvest in the Stikine River, a minimum of 4,000 and a maximum of 30,000 sockeye salmon, depending on the projected size of the run. The U.S. fisheries in District 106 - 108 are allowed to harvest the remainder of the TAC. The TAC is the fish in excess of the Stikine River escapement goal of 60,000 fish.

In-season knowledge of the Stikine contribution to the District 106 - 108 catches, the magnitude of the catch in the Canadian Stikine River fishery, and the sockeye salmon escapement level in the Stikine are necessary to implement the entitlements set forth in the U.S./Canada treaty. There were two major problems in implementing the negotiated management plan for Sumner Strait - Stikine River fisheries. First, the estimates of Stikine River catches in the District 106 - 108 gillnet fishery had to be developed, which was complicated by the complex mixture of stocks in that fishery. Second, a method for enumerating Stikine River sockeye salmon escapement had to be developed.

An inseason SPA study was initiated in 1982 to estimate stock-specific catches in the District 106-108 gillnet fishery. For management purposes the catches had to be classified into three stock groups, the Alaska coastal, Nass/Skeena River and Stikine River. However scale patterns do not cluster by these three areas, and higher order models had to be developed depending on age. The stocks considered included Nass/Skeena River, two groups of stocks within the Alaska group (so called Alaska I and Alaska II), and the two stocks within the Stikine River (Taltan Lake and mainstem Stikine River). The SPA study is too detailed to review here and the reader is referred to Jensen and Frank (1988). The SPA study did find significant differences in scale patterns among these stock groups. Estimates of stock composition of the District 106 - 108 fishery, based on SPA, are available for the years after 1982, (Figure 28).

The SPA study was successful because the growth environments in the Canadian and Alaska nursery lakes are very different. The Alaskan lakes occur in coastal areas, with cool summertime temperatures and relatively low nutrient concentrations due to rapid flushing. The Canadian lakes are inland, highly stratified, and productive with relatively warm summertime temperatures.

Estimates of the sockeye salmon escapement to the Stikine River are problematic. A portion of the run is enumerated at the weir site at the outlet to Tahltan Lake. However, the mainstem Stikine component is not available to any visual enumeration due to the very turbid water conditions in the mainstem river. The feasibility of hydro-acoustic enumeration was examined. This technology was found to be un-feasible because of expense and imprecision due to the low signal to noise ratios and low fish densities found in the Stikine River. Total sockeye salmon escapements to the Stikine River are estimated by expansion of the total Tahltan run (catch in Canadian fishery plus escapement at the weir) by the proportion of Tahltan fish in the population of sockeye salmon entering the Stikine River. Stock-specific catches in a lower river test fishery are used to estimate the proportion of Tahltan fish in the population of sockeye entering the river. The total sockeye salmon estimate requires stock identification of catches in the Canadian fishery as well as catches in the test fishery. The stock identification of these catches has been done with scale pattern analysis (Jensen and Frank 1988). In subsequent years a combination of parasite and egg diameter data will be used (Wood et al. 1987). Since the timing of the mainstem Stikine is earlier than the Tahltan (Figure 29), the estimate of the proportion of Tahltan in the escapement is taken to be the average of the proportion of the Tahltan fish in the lower river test fishery weighted by the total sockeye salmon abundance as indexed catch per unit effort.

A more through review of the application of SPA to management of the District 106-108 drift gillnet fishery for sockeye salmon, which occurs in Sumner - Clarence Strait, is provided in Marshall et al. (1987).

Yukon River Chinook Salmon Fisheries

The Yukon River, with a drainage of 860,000 km^2, is the largest river in Alaska and the fourth largest in North America. The Yukon River flows over 3,200 km from its source in northern British Columbia to the Bering Sea. About 60% of system is in Alaska. Chinook salmon spawning occurs in 100 Alaskan streams and 55 Canadian streams (Brannian 1989). Major spawning areas include the Andreafsky, Anvik, Nulato, Gisas, Chena, and Salcha rivers in Alaska (Figure 30) and Tatchun Creek, Little Salmon River, Big Salmon River, and the Nisutlin River in Canada, (Figure 31).

Inriver commercial harvesting of Yukon River chinook salmon occurs from the river mouth into Canada. The Alaska portion of the drainage has been divided into six fishing districts. Districts 1 through 5 divide the main stem from the mouth to the U.S.-Canada border. District 6 represents the Tanana River (Figure 30). In Canada commercial fishing is allowed in the main stem Yukon River upstream from the U.S.-Canada border to Tatchun Creek (Figure 31). Fishermen in Alaska are licensed for set and drift gillnets in Alaskan Districts 1 - 3, and either gillnets or fish wheels in Districts 4-6. Fishermen in Canada can use either gillnets or fishwheels, though most fish gillnets during the chinook salmon season.

The harvest of chinook salmon for personal or subsistence use is allowed throughout the Alaska portion of the Yukon River drainage. Over 1,000 families, mostly Native American, in 38 villages participate in the subsistence fishery. In Canada 12 different Indian bands utilize chinook salmon for personal consumption. The domestic fishery is open to a few non-native families living in remote areas.

In addition to the inriver commercial and subsistence fisheries, the Yukon River chinook salmon are susceptible to harvest in ocean fisheries. Immature and maturing Yukon River chinook salmon are caught in highseas salmon fisheries in the Bering Sea and North Pacific Ocean and are caught as bycatch in trawl fisheries in the Bering Sea.

Fishery managers face difficult conservation and allocation problems with the Yukon chinook salmon stocks. The conservation problem is greatly exacerbated by the gauntlet nature of the fisheries and the upriver stocks being exploited in a greater number of fisheries than the lowerriver stocks. The are many diverse user groups for this limited resource. Since the Yukon chinook stocks are fully utilized, any decline in stock abundance or proposal for increased harvest by one user group requires allocation by the regulatory agency. A substantial component of the Yukon River chinook salmon run originates in the upriver spawning areas which are in Canada. The fish of Canadian origin have been historically exploited in the Alaskan portion of the Yukon drainage. Negotiations are currently underway to develop an "equitable" allocation of the chinook salmon among U.S. and Canadian fishermen.

A scale pattern analysis study was initiated in 1981 to estimate the stock-specific catches in the various Yukon River chinook salmon fisheries (McBride and Marshall 1983). Estimates of stock-specific catches for Yukon River chinook salmon have been available since 1983 (see Brannian 1983 for background literature). Escapement scales of known origin are grouped into lowerriver, middleriver, and upriver stocks, and used to construct a three way linear discriminant model for 1.3 and 1.4 age classes. Note that the lower and middleriver stocks are in the United States and the upperriver stocks are in Canada. The model was applied to catch scales from the Alaska Districts 1 - 6 and the Canadian fishery.

Brannian (1989) has used the estimates of upperriver chinook salmon catches in the various fishing districts together with estimates of escapement of the upperriver portion of the run (Milligan et al. 1985) to estimate the rate of exploitation on the upperriver run. The estimated rates of exploitation can be used to reconstruct the components of the lower, middle, and upperriver runs (i.e. catch by district and escapement). The method of run reconstruction assumes that rate of exploitation on the lower and middleriver runs is the same as that estimated for the upperriver run in the respective fishing district (Brannian 1989).

The run reconstruction demonstrated that significant interceptions of upperriver stocks occurred in the Alaskan fisheries (Figure 32). The rate of exploitation by all Yukon River fisheries on the lower, middle, and upperriver Yukon chinook salmon runs averaged 48%, 60%, and 82%, respectively, for the years 1982 - 1986. It is not known whether the high rates of exploitation on the upperriver run can be sustained. It is likely that the lower and middle river chinook stocks are under utilized and the upperriver chinook stocks are over-utilized.

The linear discriminant models were applied to the catches in the lower river test fishery to examine potential differences in run timing among the Yukon River chinook salmon stocks. The lowerriver chinook salmon stocks appear to have an earlier run timing than the upper and middleriver stocks which have similar run timing (Figure 33). The potential exists for implementation of more stock-specific management strategies in the lower river fishery.

South Alaska Peninsula June Fishery

Migrating sockeye and chum salmon have been harvested in the South Unimak and Shumagin Islands fisheries during June since 1911. The chum salmon harvest is incidental to the more intensely managed sockeye salmon harvest. Several tagging studies conducted during the period 1923, 1956-1983 (Brannian 1984) have showen that a substantial fraction of the sockeye and chum salmon available to these fisheries were not of local origin. For chum salmon the pattern of tag recoveries indicated that these fisheries were intercepting fish primarily of western Alaska origin, although tags were recovered from widely dispersed areas throughout the Alaska Peninsula, Japan, the U.S.S.R., British Columbia, and Puget Sound (Brannian 1984). The pattern of tag recoveries indicated that these fisheries were intercepting primarily Bristol Bay sockeye salmon with minor interceptions of sockeye salmon bound for North Alaska Peninsula river systems.

Considerable controversy has developed in recent years over the level of chum salmon catches in these fisheries. During the period 1980 - 1987, chum salmon harvests in the South Unimak and Shumagin Islands fisheries have averaged 566 thousand fish, including a record harvest of chum salmon during 1982 (1.1 million fish) and 1983 (784 thousand fish). These large catches are well above the average harvests for the periods 1970-1979 (306 thousand fish) and 1960-1969 (186 thousand fish). They are a result of the large sockeye salmon catch quotas established in response to increased sockeye salmon returns to Bristol Bay. Sockeye salmon catch quotas are based on a fixed percentage of the forecasted harvest in the Bristol Bay inshore districts. While the current management strategy appears adequate to maintain a consistent level of exploitation on Bristol Bay sockeye salmon, this fishing strategy is independent of chum salmon abundance. Exploitation rates for chum salmon may have reached a level where the inshore returns of some stocks may be adversely impacted. The potential western and central Alaska fisheries affected by the South Alaska Peninsula June fisheries are shown in Figure 34.

In recent years the inshore returns of several western Alaskan chum salmon runs, most notably Yukon River fall chum and Kotzebue Sound chums, have been less than expected (Buklis and Barton 1984, Buklis 1987). It is suspected that interceptions in the South Unimak and Shumagin Island fisheries may have contributed to these lower than expected returns. Most western Alaskan chum salmon stocks are fully utilized in terminal commercial and subsistence fisheries. It is impossible to sustain chum salmon production in the face of increased exploitation in marine interception fisheries. Since marine fisheries occur before terminal harvests each year, the long-term result of increased marine exploitation is an inevitable reduction in harvest levels in the respective terminal fisheries. However, it is impossible to quantify the impact of the South Unimak fishery on western Alaskan chum production without adequate knowledge of the stock composition of the catch.

A comprehensive tagging study was conducted in 1987 to provide estimates of the stock composition of the South Peninsula June fishery catches (Eggers et al. 1989). The tagging study was also envisioned to provide evidence for differential migratory timing among stocks in the South Peninsula fishery. There has been concern that Yukon fall chum salmon stocks may be more vulnerable to the South Peninsula Fishery because their migratory timing is concurrent with the South Peninsula fishery.

A total of 6,987 sockeye were tagged with 5,442 and 1,545 released in the Unimak and Shumagin Districts, respectively. A total of 6,323 chum salmon were tagged with 3,495 and 2,828 tagged fish released in the Unimak and Shumagin Districts, respectively. The releases were timed to coincide with the timing and area (Figure 35) of the South Peninsula June fishery. Tagging occurred June 6 through July 2 on days when the South Peninsula June fishery was closed (Figure 36).

The stock composition of the 1987 catches of sockeye and chum salmon was estimated based on the release and subsequent recovery of tagged fish in western Alaska, central Alaska, and Asian terminal fishing areas. As of September 9, 1989, 1,921 or 27.5% of the total releases of sockeye salmon tags and 843 or 13.3% of the total releases of chum salmon tags were recovered in terminal fisheries through a voluntary recovery program. Sockeye salmon recoveries came strictly from Alaskan fisheries. The chum salmon releases were far ranging. Recoveries included 37 in Japanese coastal fisheries and hatcheries, 13 in coastal USSR fisheries, three in Kotzebue Sound, and one in the coastal British Columbia fishery.

The apportionment was based on expanded recoveries in various fisheries conducted in the terminal harvest areas of the respective stock of origin. Recoveries were expanded to total return for under-reporting of recoveries, for direct tagging mortality, and for delayed mortality which includes natural mortality and tag shedding. The relative magnitude of the expanded recoveries for the respective stocks provided an estimate of the stock composition of the South Peninsula June catches. The expansions to total returns are based on the best available information on catches and escapements to terminal harvest areas. The expansions for under-reporting were based on the reported fraction from a concurrent fishery sampling program for recoveries in western and central Alaska. Estimates of mortality and tag loss were made by fitting the expanded number of recoveries to numbers actually released in the Unimak and Shumagin areas.

Bristol Bay stocks dominated the sockeye salmon releases, and were 83.8 and 53.7 percent of the Unimak (Figure 37) and Shumagin releases, respectively. The North Peninsula, South Peninsula, Chignik, and central Alaska (i.e., Kodiak, Cook Inlet, and Prince William Sound) stocks were collectively more important in the Shumagin sockeye releases, collectively contributing 46.3% of the Shumagin releases compared to 16% in the Unimak releases.

The stock composition of the chum salmon releases differed markedly from that of the sockeye salmon releases. There was a more diverse mixture of stocks, with no particular stock dominating the releases (Figure 38). Tagged fish of Asian origin were significant and constituted 18% of the Unimak and 44.8% of the Shumagin releases. Tagged fish of Bristol Bay origin were the most abundant stock in the Unimak releases, accounting for 40.0% of the releases. Tagged fish of Asian origin were the most abundant stock in the Shumagin releases, with tagged fish of Japanese coastal origin accounting for 36.5%. Of the Alaskan stocks, Bristol Bay and Kuskokwim stocks were most abundant in the releases, with the combined stocks accounting for 59% and 49.9% of the Unimak and Shumagin releases, respectively.

There was little difference in mean date of release among recoveries of chum salmon in various western and central Alaska fisheries, indicating that almost total overlap in timing occurs for western and central Alaska chum salmon stocks in the area of the South Peninsula June fishery.

Prince William Sound Pink Salmon Fishery

The Prince William Sound (PWS) area of southcentral Alaska (Figure 39) has supported a commercial purse seine harvest of pink salmon since 1986. Over 900 anadromous streams in PWS support pink salmon populations. During the period 1910 - 1970, harvests ranged from a high of 12 million in 1945 to less than 1 thousand in 1959. A dramatic decline in salmon stocks occurred in PWS and statewide in the early 1970's. In response to this decline, the state of Alaska embarked on an aggressive enhancement program. An integral segment of the enhancement program was the construction of numerous hatcheries, some of which are owned by the state of Alaska, others, built and operated by private nonprofit (PNP) corporations with financing secured through the state of Alaska. Currently there in one state of Alaska hatchery (Cannery Creek) and three PNP hatcheries (AFK, Esther, and Solomon Gulch) that produce pink salmon operating in Prince William Sound. A fifth hatchery, the Main Bay hatchery, is operated by the state of Alaska and produces sockeye and coho salmon. By law PNP hatcheries are allowed to sell fish returning to the hatchery to support their operations. In addition, the regional association PNP hatcheries are funded through a self imposed tax on commercial fish catches.

The first PNP hatchery began operations in 1975 in PWS. In 1989 hatchery production of pink salmon in PWS is expected to be 27.5 million fish. This level of hatchery production is expected to be greater than wild stock production levels, except in years where wild stock production is exceptional.

There are eight fishing districts in PWS (Figure 39). The vast majority of the pink salmon harvests occur in the purse seine fishery. All purse seine harvests are of mixed stocks, and in recent years over 50% of the pink salmon catch has occurred in the Southwestern District. The Southwestern District catch includes a mixture of wild stocks destined for the western and northern portions of PWS as well as hatchery stocks from three of the four hatcheries (AFK, Esther, and Cannery Ck.).

Management of this complex mixed stock fishery is extremely difficult without the ability to differentiate between wild and hatchery stocks. Time and area closures are used to assure adequate wild stock escapements to natal streams and sufficient hatchery escapements for brood stock and cost recovery. There exists extreme variability in the magnitude of pink salmon returns from year to year. Production is not well correlated among hachery and wild stocks. Without knowledge of the hatchery and wild stock contributions to the catches it is almost impossible to efficiently manage the fishery, such that both wild stock escapement goals and hatchery brood stock and cost recovery requirements are met. There is great danger of over-harvesting the wild stocks in situations of weak wild stock and strong hatchery stock runs.

In 1986 the Alaska Department of Fish and Game (ADF&G) initiated feasibility study using half-length coded wire tags (HLCWT) to differentiate amont wild stocks and individual hatchery stocks in the PWS pink salmon fishery (Peltz and Geiger 1989). The study was designed to test the practicality of tagging large number of pink salmon with HLCWT and to estimate the hatchery/wild stock contribution in the Southwestern District. Application of HLCWT was conducted at the AFK, Ester, and Cannery Creek hatcheries in the spring of 1986. Over 200,000 tags were applied to pink salmon fry at each hatchery. Tagging methods are described by Peltz and Miller (in press).

During July and August 1987, commercial catches of adult pink salmon were sampled for fish without adipose fins (adipose fins were removed at the time of marking with HLCWT) at the four largest processors of PWS pink salmon. At each processing facility a technician scanned as many fish as possible on the sorting line. The total number of fish actually examined for missing adipose fin was tallied. Those fish with missing fins were removed and heads were excised, frozen, and later processed for HLCWT. Brood stock returns at each hatchery were also sampled for marked fish to determine the rate of mark occurrence at return.

The estimated catch of the hatchery stock marked with tag code t (C^t) is:

$$C^t = \sum_i x^t_i \, (N_i/s_i) \, (1/p^t)$$

where, x^t_i is the number of tags recovered with code t in fishery, N_i is the number of fish caught in fishery i, s_i is the number of fish in the catch of that fishery sampled for HLCWT, and p^t is the proportion of fish in the t release group marked with HLCWT.

Hatchery stocks represented 13.7 million of the 26.1 million pink salmon caught in 1987. Hatchery stocks were dominant in the Southwestern District catches (Figure 40); but hatchery stocks were a minor component in the Eastern and Southeastern Districts indicating the entry of hatchery stocks into PWS was through the Southwestern District. The study demonstrated that it is practical to use half length coded wire tags to study hatchery contribution.

LITERATURE CITED

Brannian, L.K. 1984. Recovery distribution of chum salmon (*Oncorhynchus keta*) tagged in the North Pacific offshore of the Alaska Peninsula and Eastern Aleutian Island chain. Informational Leaflet No. 237, Alaska Dept. of Fish and Game, Juneau, AK. 30 pp.

Brannian, L.K. 1989. Estimates of total return, exploitation, rate, and migratory timing of chinook salmon runs in the Yukon River, 1982 - 1983. Fishery Research Bulletin No. 89- . Alaska Department of Fish and Game, Juneau, AK. 99802 (in review)

Buklis, L.S. 1987. Yukon fall chum population analysis for Alaska Board of Fisheries Meeting, December, 1987. Unpublished Memo, Alaska Dept. of Fish and Game, 333 Raspberry Rd., Anchorage, AK 99502. 19 pp.

Buklis, L.S., and L.H. Barton. 1984. Yukon River fall chum salmon biology and stock status. Informational Leaflet No. 239, Alaska Dept. of Fish and Game, Juneau, AK. 67 pp.

Cross, B.A., and B.L. Stratton. 1987. Origins of sockeye salmon in fishing districts within east side Bristol Bay in 1986 based on analysis of scale patterns. Technical Fishery Report No. , Alaska Department of Fish and Game, Juneau, AK. 99802

Cross, B.A., and B.L. Stratton. 1988. Origins of sockeye salmon in fishing districts within east side Bristol Bay in 1987 based on analysis of scale patterns. Technical Fishery Report No. , Alaska Department of Fish and Game, Juneau, AK. 99802

Cross, B.A., and B.L. Stratton. 1989. Origins of sockeye salmon in fishing districts within east side Bristol Bay in 1988 based on analysis of scale patterns. Technical Fishery Report No. , Alaska Department of Fish and Game, Juneau, AK. 99802

Dahlberg, M. 1968. Analysis of the dynamics of sockeye salmon returns to the Chignik lakes, Alaska, Ph.D. dissertation, Univ. of Washington, Seattle. WA 337 p.

Eggers, D.M., and D.E. Rogers. 1987. The cycle of runs of sockeye salmon (*Oncorhynchus nerka*) to the Kvichak River, Bristol Bay Alaska: cyclic dominance or depensatory fishing. p. 343 - 366. *In* H.D. Smith, L. Margolis, and C.C. Wood [ed.] Sockeye salmon (*Oncorhynchus nerka*) population biology and future management. Can. Spec. Publ. Fish. Aquat. Sci. 96.

Eggers, D., K. Rowell, B. Barrett. 1989. Stock composition of sockeye and chum salmon in the 1987 South Peninsula, Alaska, June fishery based on completed tag data. Alaska Dept. of Fish and Game, Div. of Commercial Fisheries, Fishery Research Bulletin (in review).

Geiger, H.J. 1989. A stock identification study in the 1988 Northern Alaska Peninsula sockeye salmon fishery, form Harbor Point to Strogonof Point. Unpubl. manuscript, Alaska Department of Fish and Game, Juneau, AK. 99802

Geiger, H.J., and H. Savikko. 1989. Preliminary forecasts and projections for 1989 Alaska salmon fisheries. Reg. Infor. Rept. No. 5j89-01, Alaska Dept. of Fish and Game, Juneau, AK. 63 p.

Jensen, K.A., and I.S. Frank. 1988. Stock compositions of sockeye salmon catches in Southeast Alaska's Districts 106 and 108 and in the Stikine river, 1987, estimated with scale pattern analysis. AK Dep. Fish and Game, Tech. Fishery Rep. No. 88-13: 77 p.

Koo, T.S.Y. 1962. Age designation in salmon. p.37-45. *In* T.S.Y. Koo [ed.] Studies of Alaska Red Salmon. Univ. Washington Publ. in Fish., New Ser., Vol. I.

Marshall, S., D. Bernard, R. Conrad, B. Cross, D. McBride, A. McGregor, S. McPherson, G. Oliver, S. Sharr, and B. Van Allen. 1987. Application of scale pattern analysis to the management of Alaska's sockeye salmon (*Oncorhynchus nerka*) fisheries. p. 307 - 326. *In* H.D. Smith, L. Margolis, and C.C. Wood [ed.] Sockeye salmon (*Oncorhynchus nerka*) population biology and future management. Can. Spec. Publ. Fish. Aquat. Sci. 96.

McBride, D.N., and S.L. Marshall. 1983. Feasibility of scale pattern analysis to identify the origins of chinook salmon (*Oncorhynchus tshawytscha* Walbaum) in the lower Yukon River commercial gillnet fishery, 1980 - 1981. Alaska Department of Fish and Game, Div. of Commercial Fisheries, Informational Leaflet 208, Juneau.

McGregor, A.J., and S.L. Walls. 1987. Separation of principal Taku River and Port Snettisham sockeye salmon (*Oncorhynchus nerka*) stocks in Southeastern Alaska and Canadian fisheries of 1986 based on scale pattern analysis. AK Dep. Fish and Game, Tech. Data Rep. No. 213: 57 p.

McGregor, A.J., and J.E. Clark. 1987. Migratory timing and escapement of Taku River salmon stocks, 1986. Final Report - 1986 salmon research conducted in Southeast Alaska by the Alaska Department of Fish and Game in conjunction with the National Marine Fisheries Service, Auke Bay Laboratory for joint U.S.-Canada interception studies. Alaska Dept. of Fish and Game, Douglas AK

McPherson, S., and S. Marshall. 1986. Estimated stock contribution, exploitation rates, and migratory timing of sockeye salmon (*Oncorhynchus nerka*) in the Lynn Canal drift gillnet fishery of 1983 based on scale pattern analysis. AK Dep. Fish and Game, Tech. Data Rep. No. 165: 39 p.

Milligan, P.A., W.O. Rublee, D.D. Cornett, and R.A.C. Johnston. 1985. The distribution and abundance of chinook salmon (*Oncorhynchus tshawytscha*) in the upper Yukon River basin as determined by a radio-tagging and spaghetti tagging program: 1982-1983. Canadian Department of Fisheries and Oceans, Canadian Technical Report of Fisheries and Aquatic Sciences 1352.

Minard, R.E., and C.P. Meacham. 1987. Sockeye salmon (*Oncorhynchus nerka*) management in Bristol Bay, Alaska, p. 336 - 342 *In* H.D. Smith, L. Margolis, and C.C. Wood [ed.] Sockeye salmon (*Oncorhynchus nerka*) population biology and future management. Can. Spec. Publ. Fish. Aquat. Sci. 96.

Peltz, L.P., and H.J. Geiger. 1989. A study of the effect of hatcheries on the 1987 pink salmon fishery in Prince William Sound, Alaska. Unpublished manuscript, Alaska Dept. of Fish and Game, Div. of Commercial Fisheries, Juneau, AK.

Peltz, L.P., and J. Miller. (in press). Performance of half-length coded wire tags in a pink salmon hatchery marking program. Proceedings of the international symposium and educational workshop on fish-marking techniques, June 27, 1988. Seattle, WA.

Pennoyer, S.P., and M.L. Nelson. 1967. Summary of Bristol Bay tagging studies, 1950 - 1966. Unpublished manuscript, Alaska Department of Fish and Game, 333 Raspberry Rd., Anchorage, AK 99503.

Pirtle, R. 1967. Annual management report. AK Dep. Fish and Game, Div. Comm. Fish., P.O. Box 669, Cordova, AK. 120 p.

Straty, R.R. 1969. The migratory pattern of adult sockeye salmon (*Oncorhynchus nerka*) in Bristol Bay as related to the distribution of their home-river waters. Ph.D. thesis, Oregon State Univ., Corvallis, OR. 243 p.

Straty, R.R. 1975. Migratory routes of adult sockeye salmon (*Oncorhynchus nerka*), in the Eastern Bering Sea and Bristol Bay. NOAA Technical Report NMF SSrf-690. United States Department of Commerce.

Swanton, C.O. 1989. Stock identification of sockeye salmon (*Oncorhynchus nerka*)in the Alitak Bay District, Southwestern Kodiak Island. MS. thesis, Univ. of Washington, Seattle, WA.

Wood, C.C., B.E. Riddell, and D.T. Rutherford. 1986. Alternative juvenile life histories of sockeye salmon and their contribution to production in the Stikine River, northern British Columbia. Can. J. Fish. Aquat. Sci. 43:

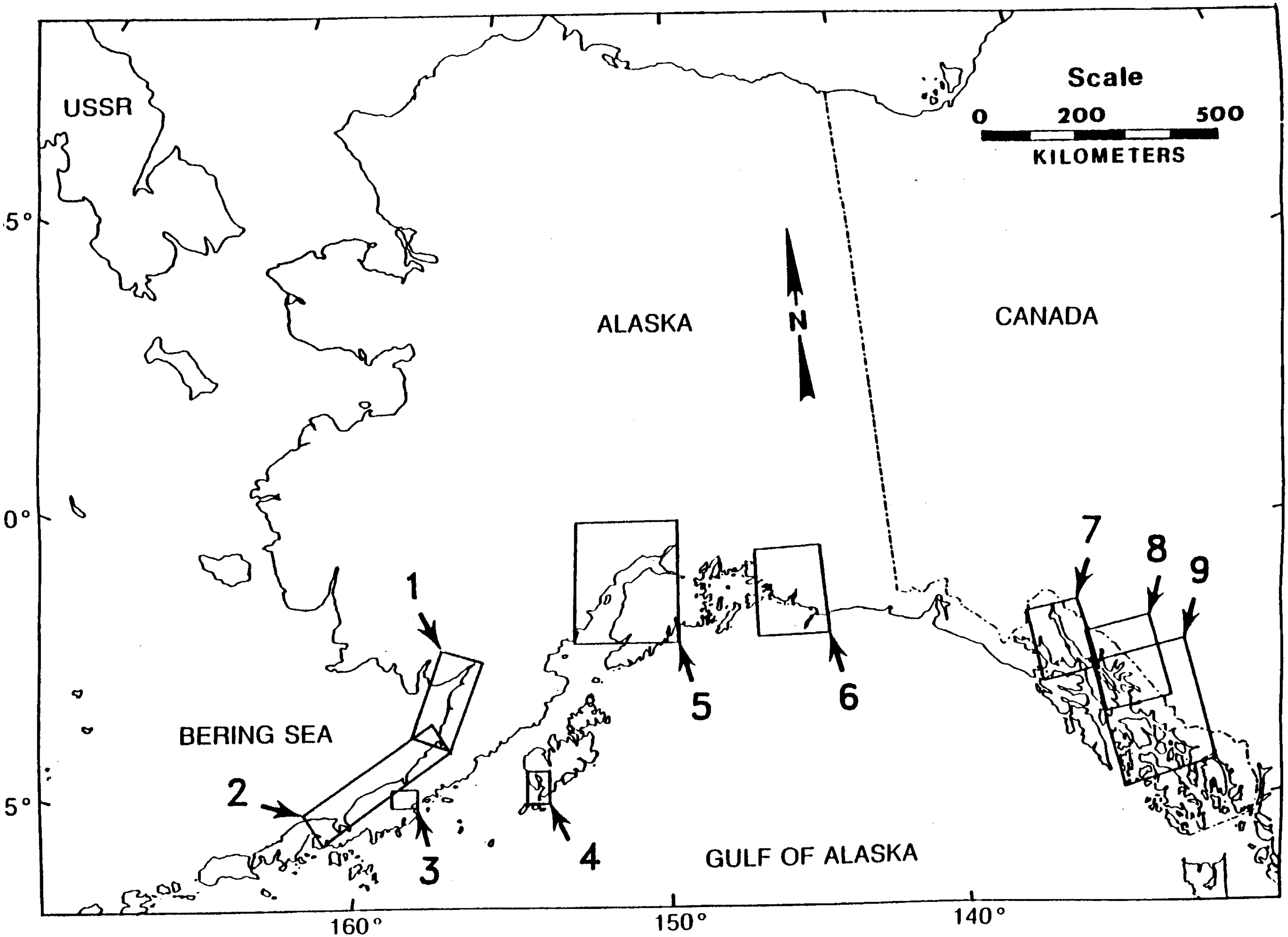


Figure 1. Location of study areas in Alaska and western Canada: (1) Bristol Bay, (2) North Alaska Peninsula, (3) Chignik, (4) Olga - Moser Bay, Kodiak Island, (5) Upper Cook Inlet, (6) Copper - Bering Rivers, (7) Lynn Canal, (8) Taku - Snettisham, and (9) Sumner Strait - Stikine River. Figure modified from Marshall et al. (1987).

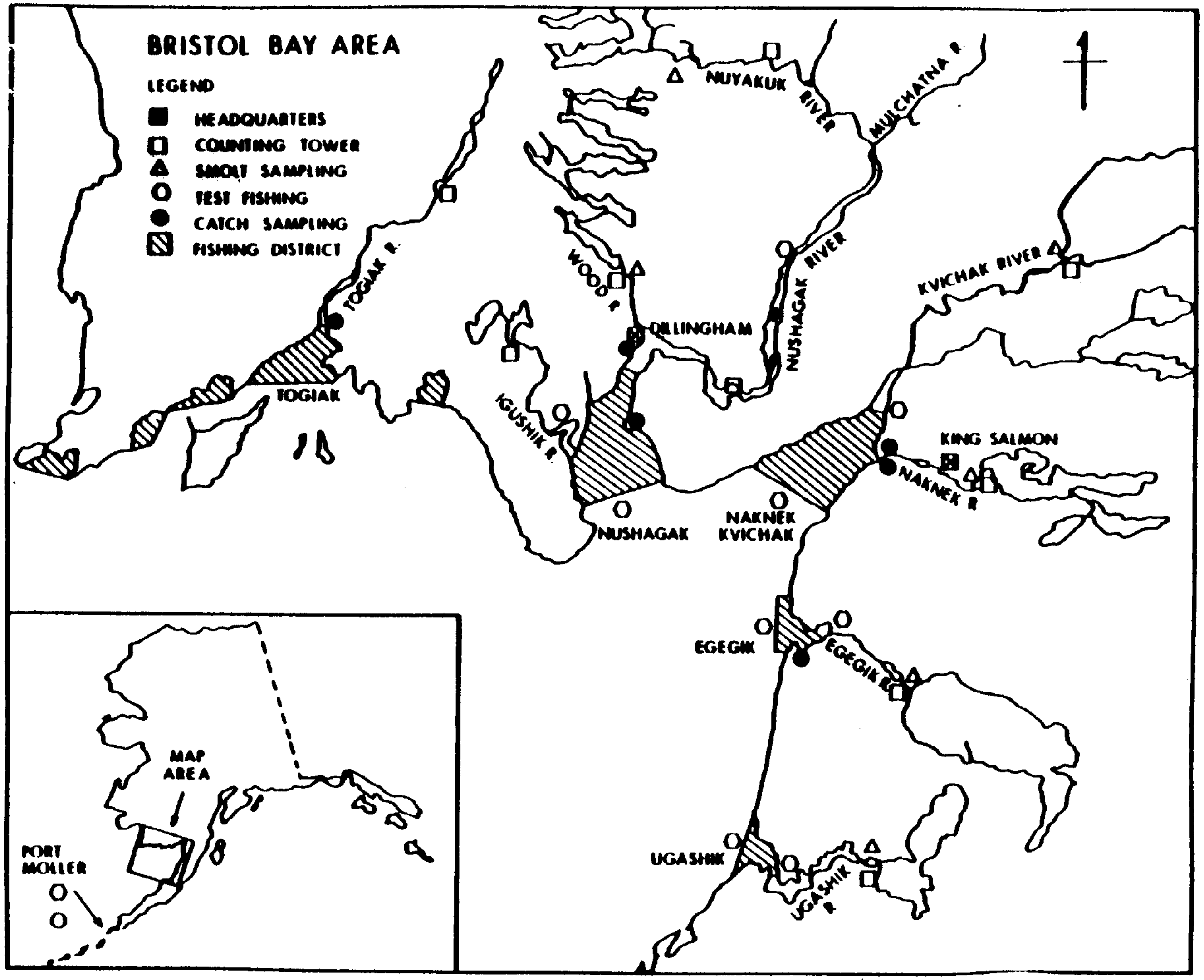


Figure 2. Bristol Bay sockeye salmon river systems, fishing districts, and sampling programs of the Bristol Bay management system.

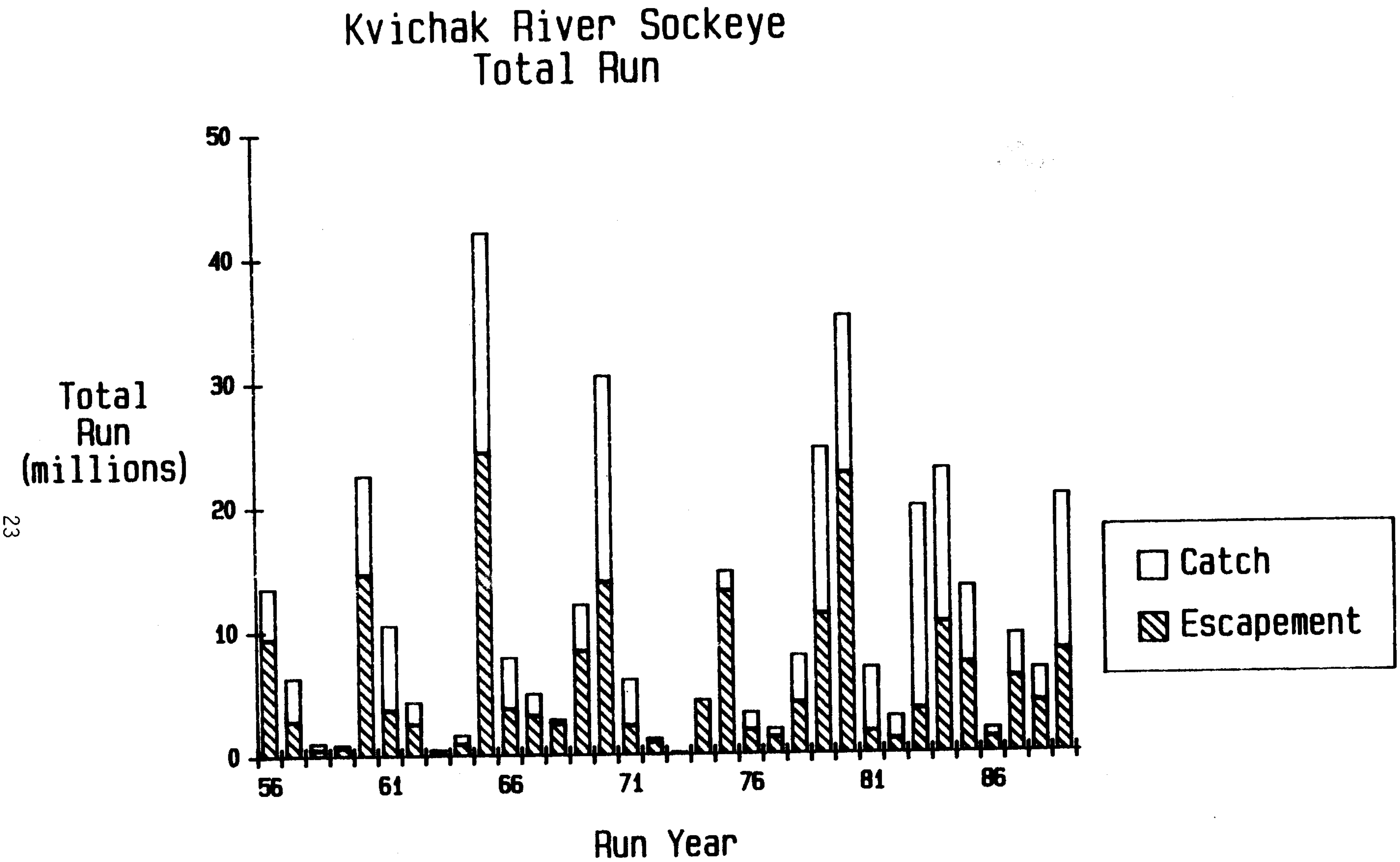


Figure 3. Total inshore run (catch + escapement) of sockeye salmon to the Kvichak River, 1956-1989.

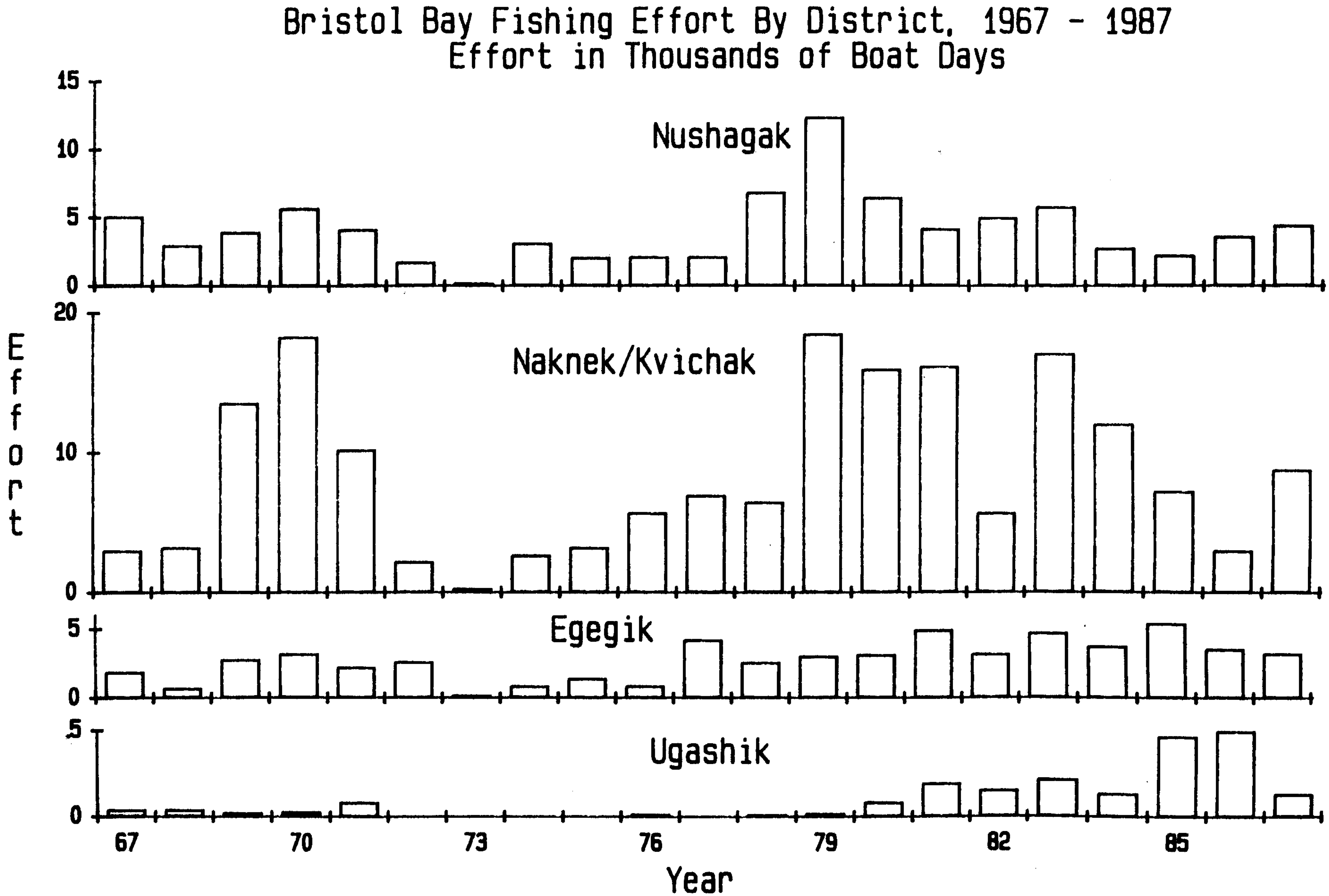


Figure 4. Fishing effort (thousands of boat days) for Nushagak, Naknek/Kvichak, Egegik and Ugashik fishing districts, 1967-1987.

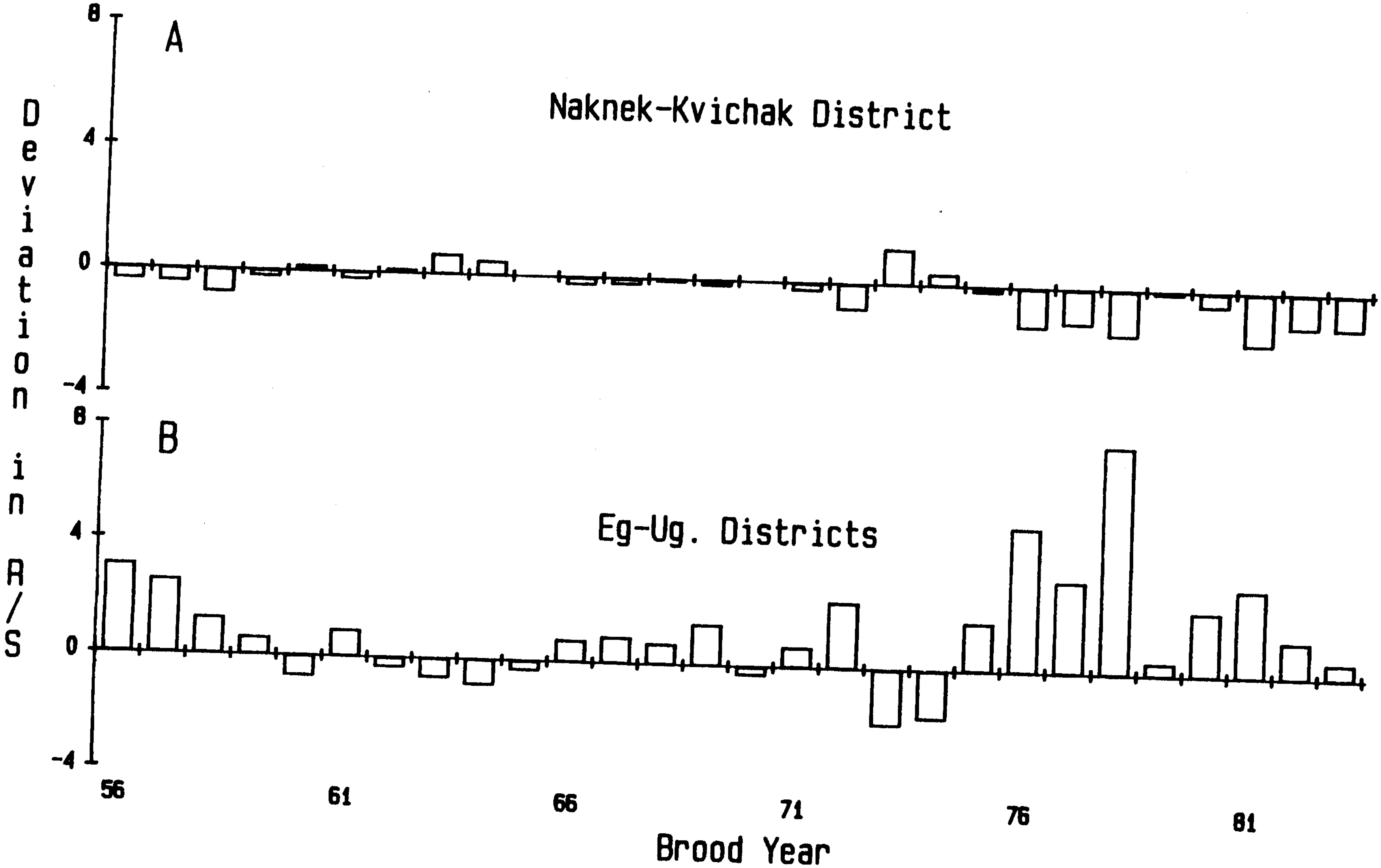


Figure 5. (A) Deviation by brood year from pooled eastside river systems return per spawner, for pooled river systems terminating in the Naknek/Kvichak District, and (B) for pooled river systems terminating in the Egegik/Ugashik District.

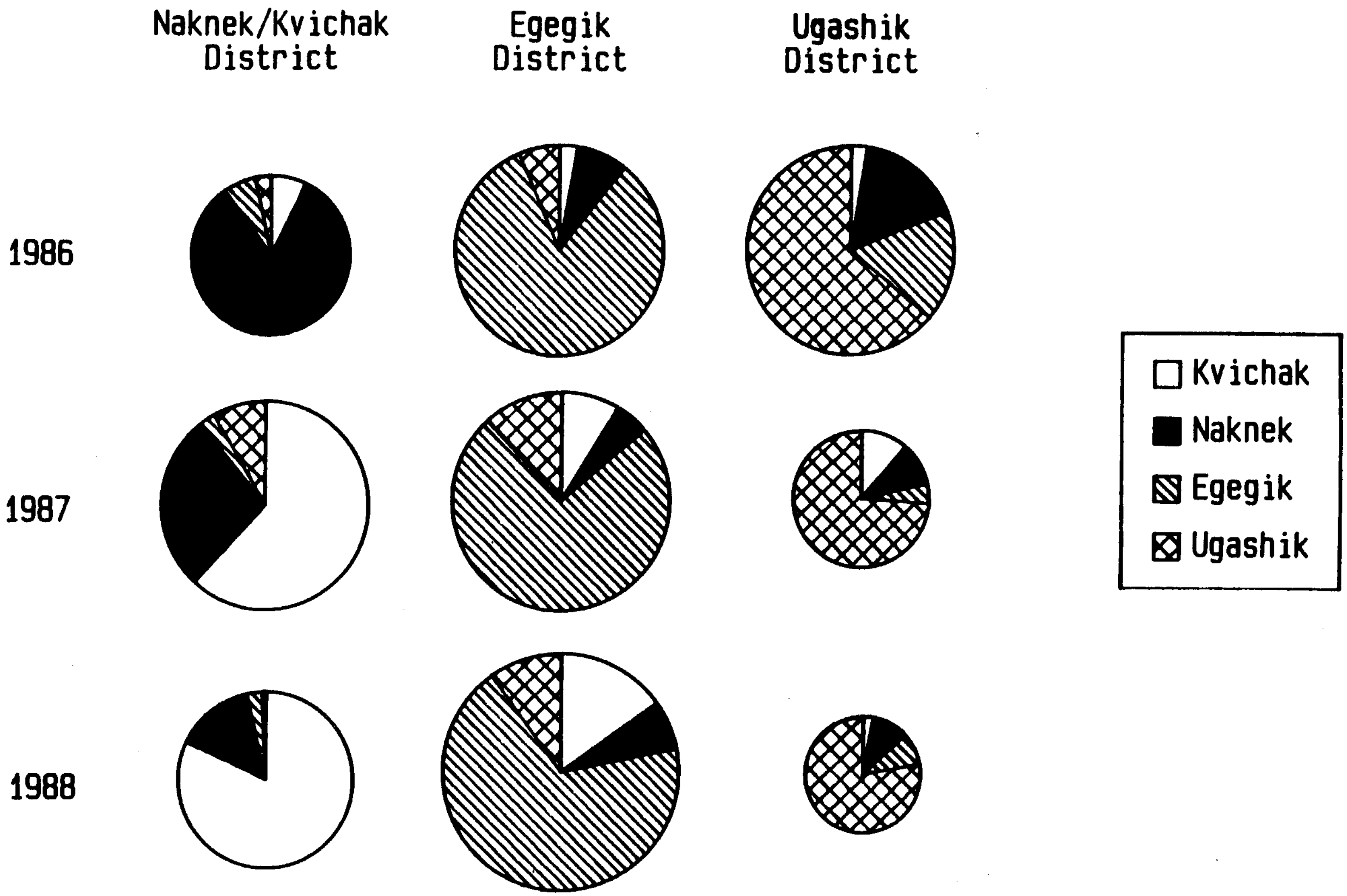


Figure 6. Estimates of stock composition, in terms of river of origin, for the total catch of sockeye salmon in the Naknek-Kvichak, Egegik, and Ugashik Districts for 1986-1988. Relative area of pie charts scale to relative catch magnitude for respective district and year.

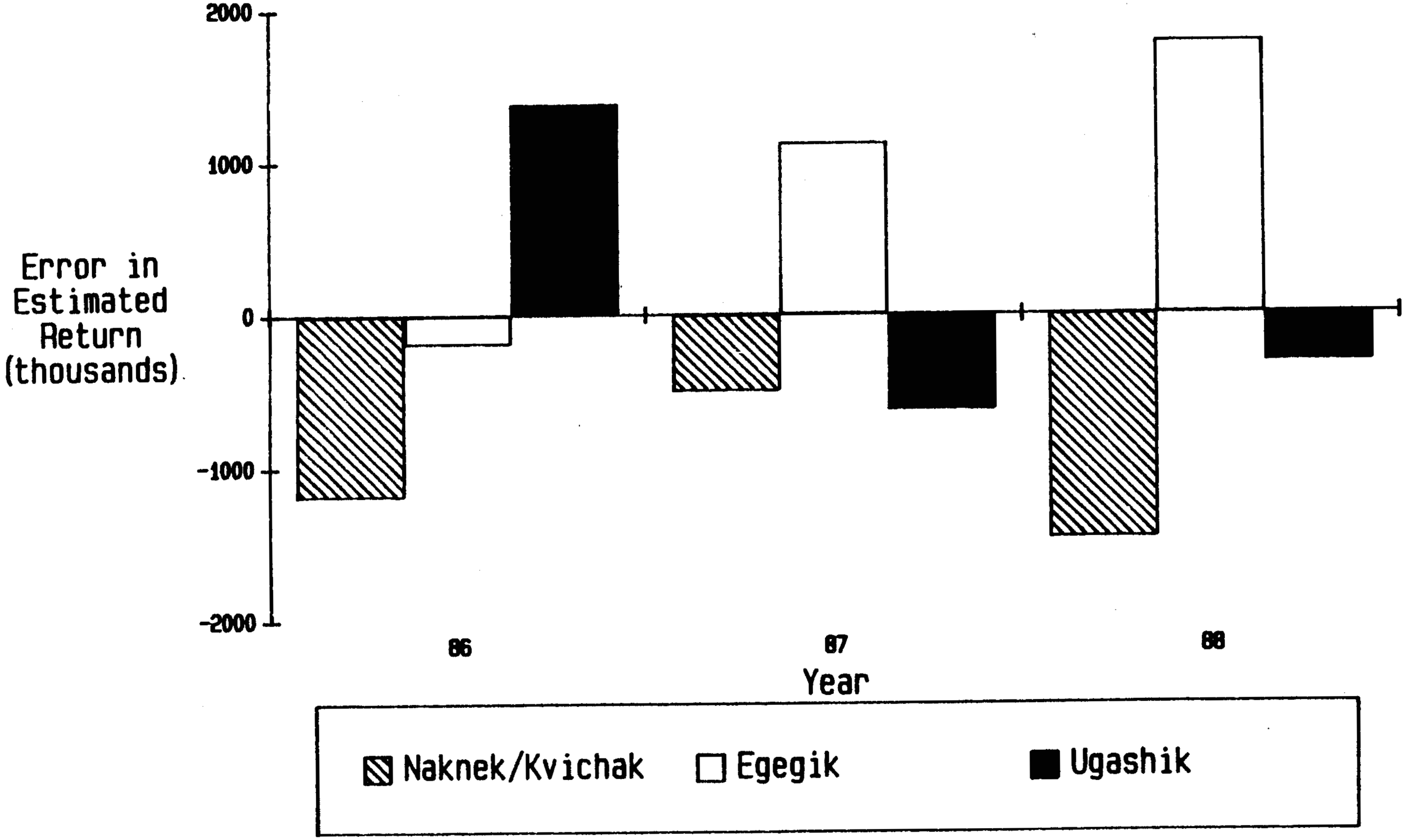


Figure 7. Difference between estimated return based on assigning district catches to river systems terminating in the respective district and return based on allocation of district catches to river of origin based on scale pattern analysis, 1986-1987.

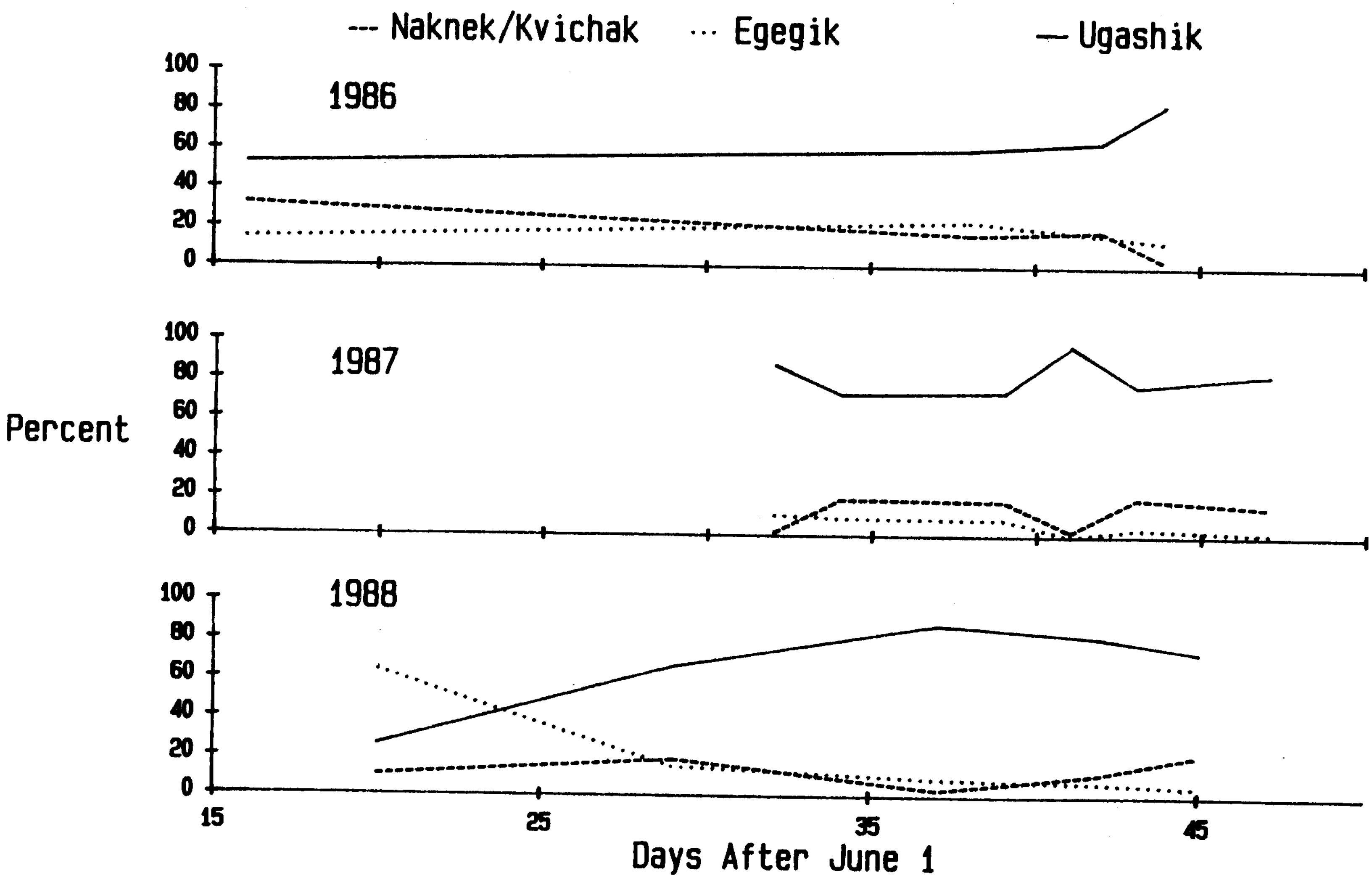


Figure 8. Stock composition of catches of sockeye salmon from Ugashik District catches through time, 1986-1988.

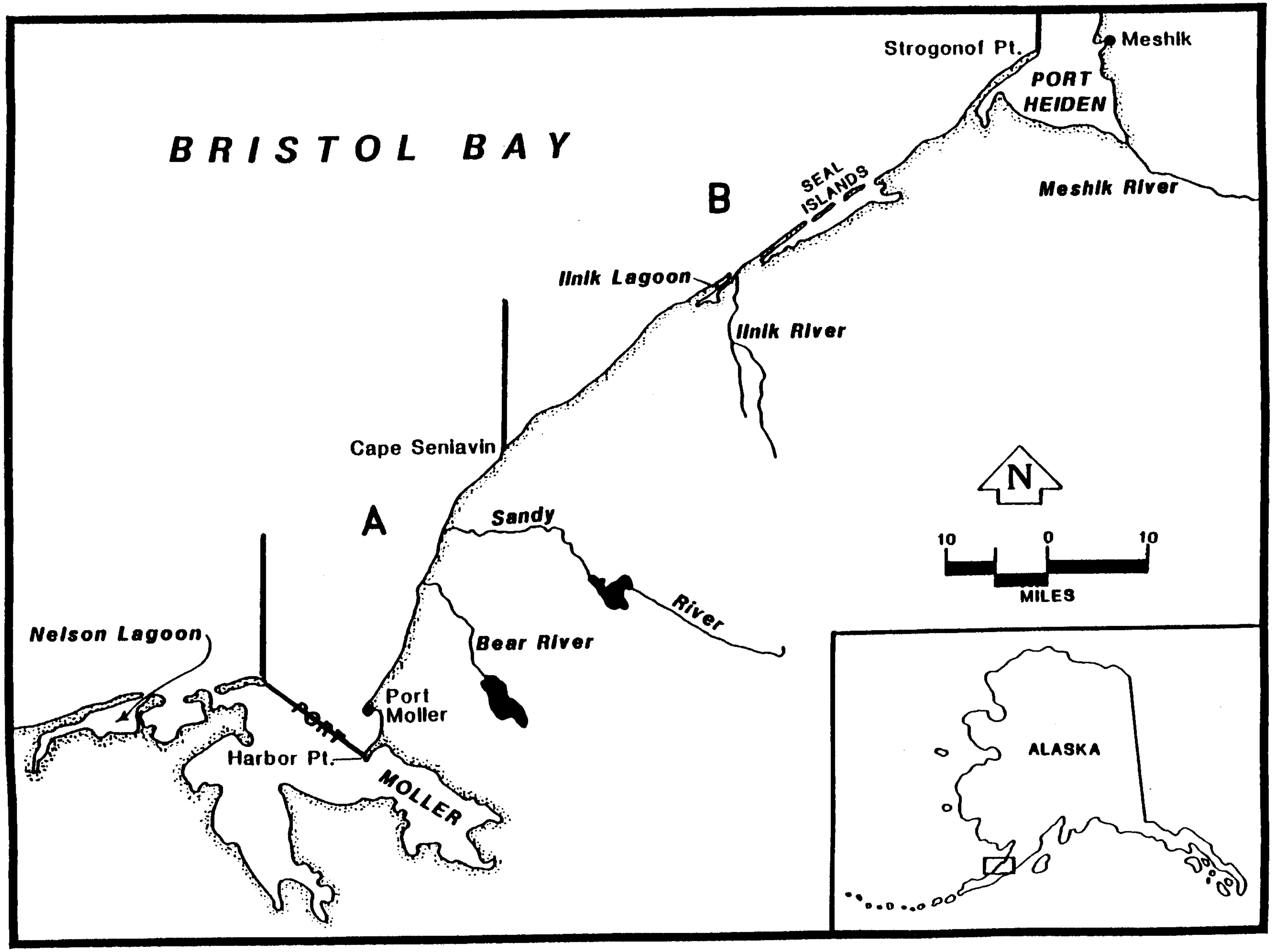


Figure 9. Harbor Point to Cape Seniavin area (A) and Cape Seniavin to Strogonof Point area (B) of the Northern District, North Alaska Peninsula Fishery Unit. Also shown are the drainages of the four principal sockeye salmon stocks (Nelson Lagoon, Bear River, Sandy River, and Ilnik Lagoon).

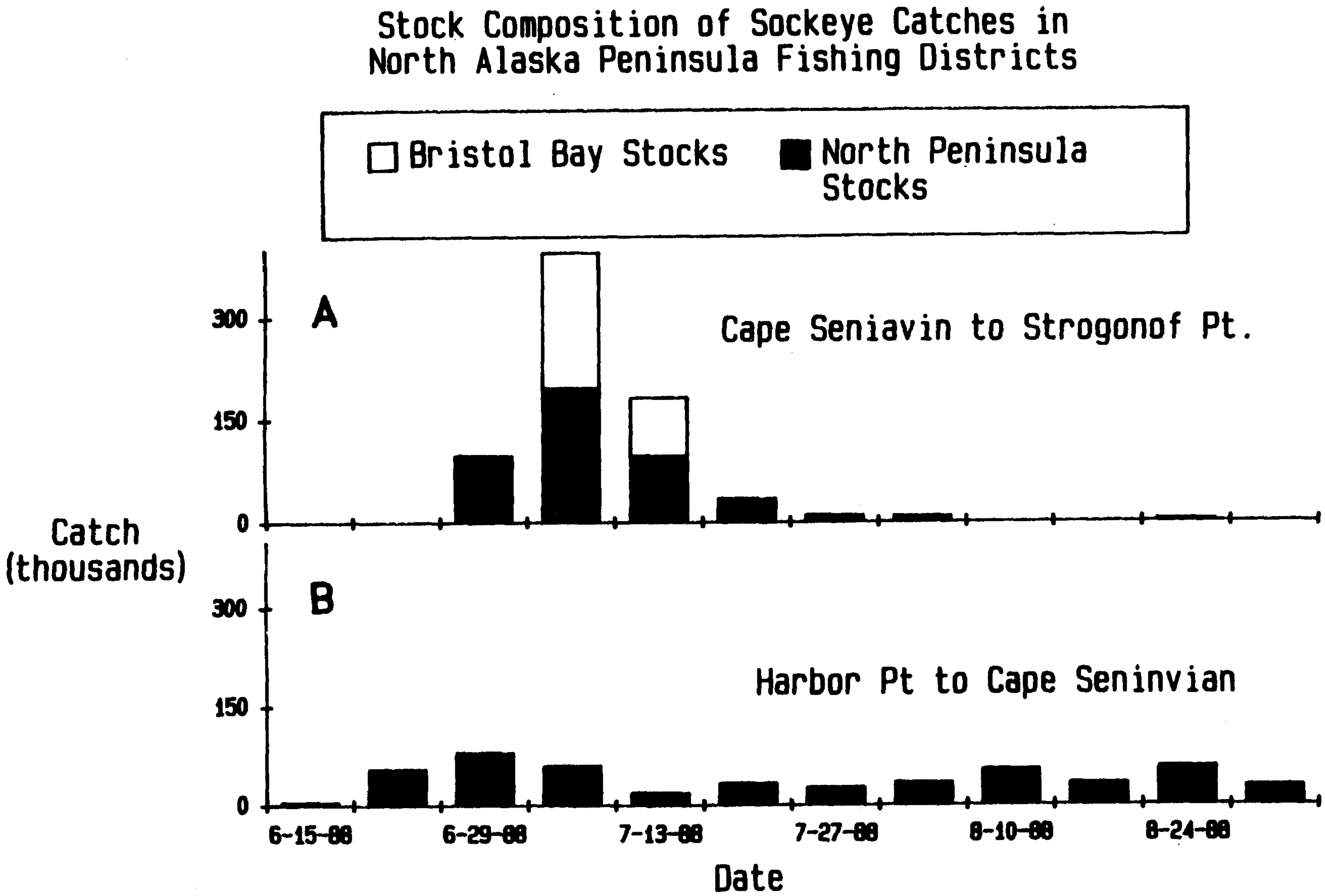


Figure 10. Stock composition, in terms of fish originating in Bristol Bay river systems and North Peninsula river systems, of sockeye salmon catches North Peninsula fisheries. Catches from A. the Cape Seniavin to Strogonof Point area, and B. the Harbor Point to Cape Seniavin area.

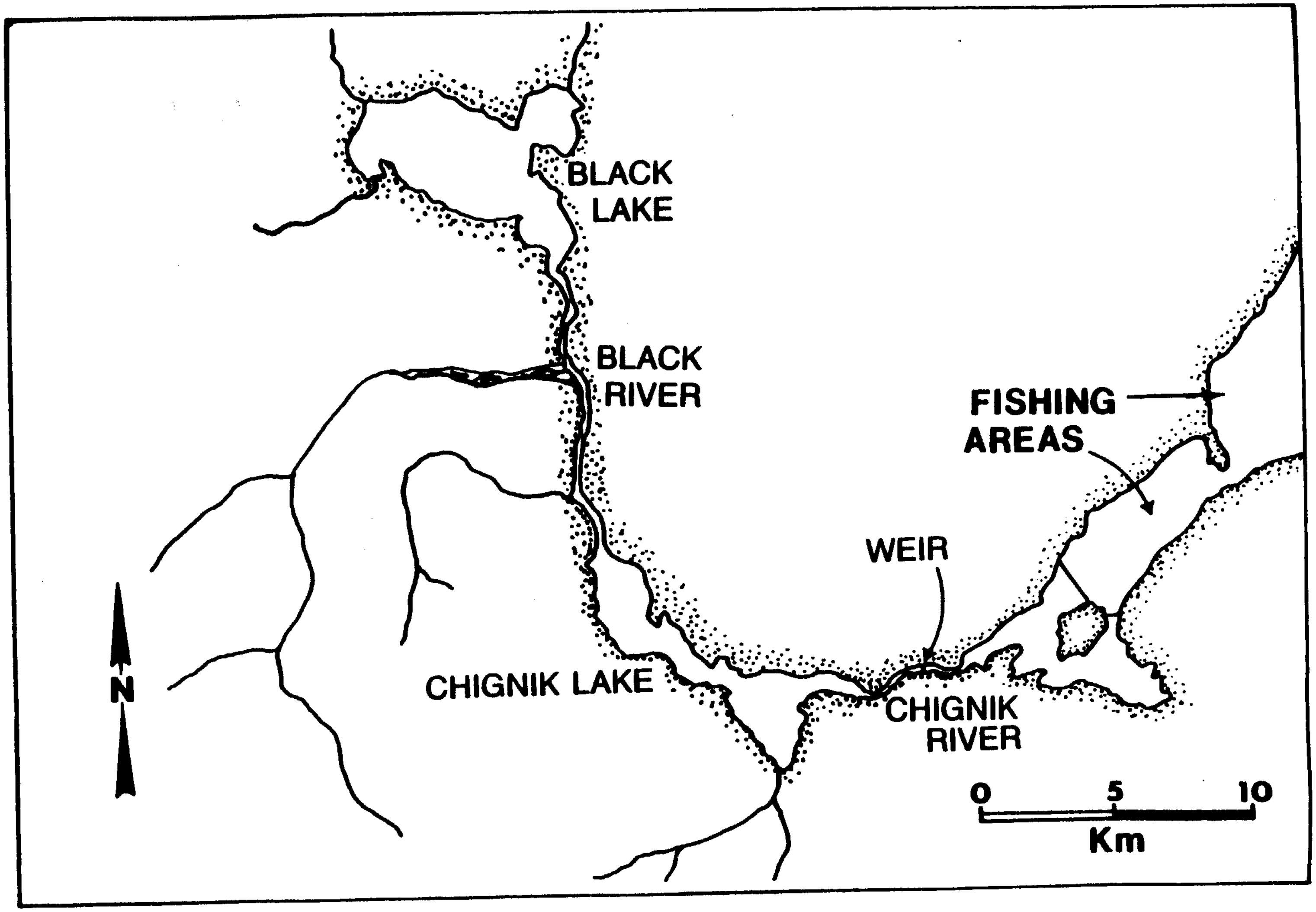


Figure 11. The Chignik and Black Lakes area showing the location of the fishery and the major sockeye salmon spawning drainages. Figure modified from Marshall et al. (1987).

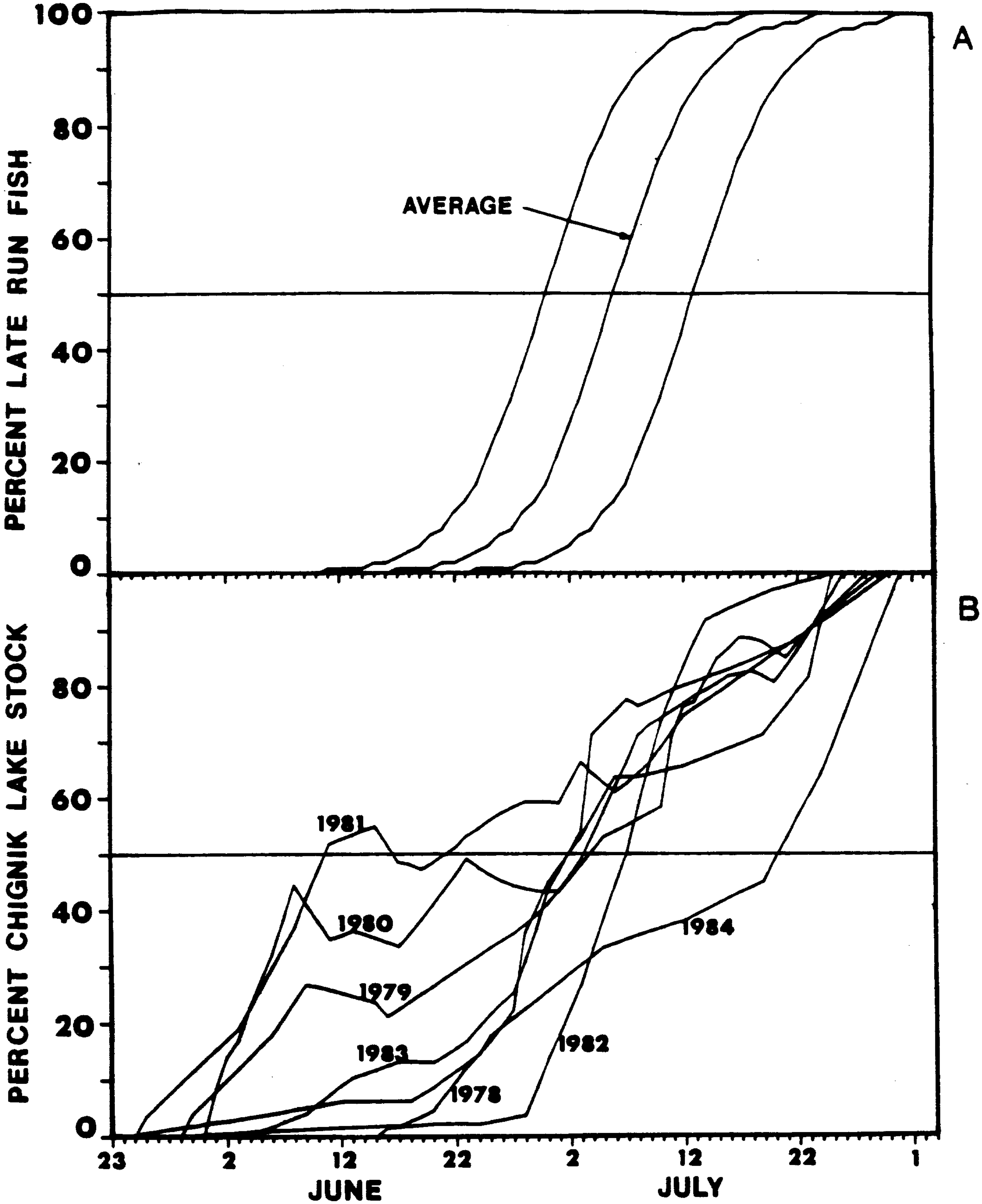
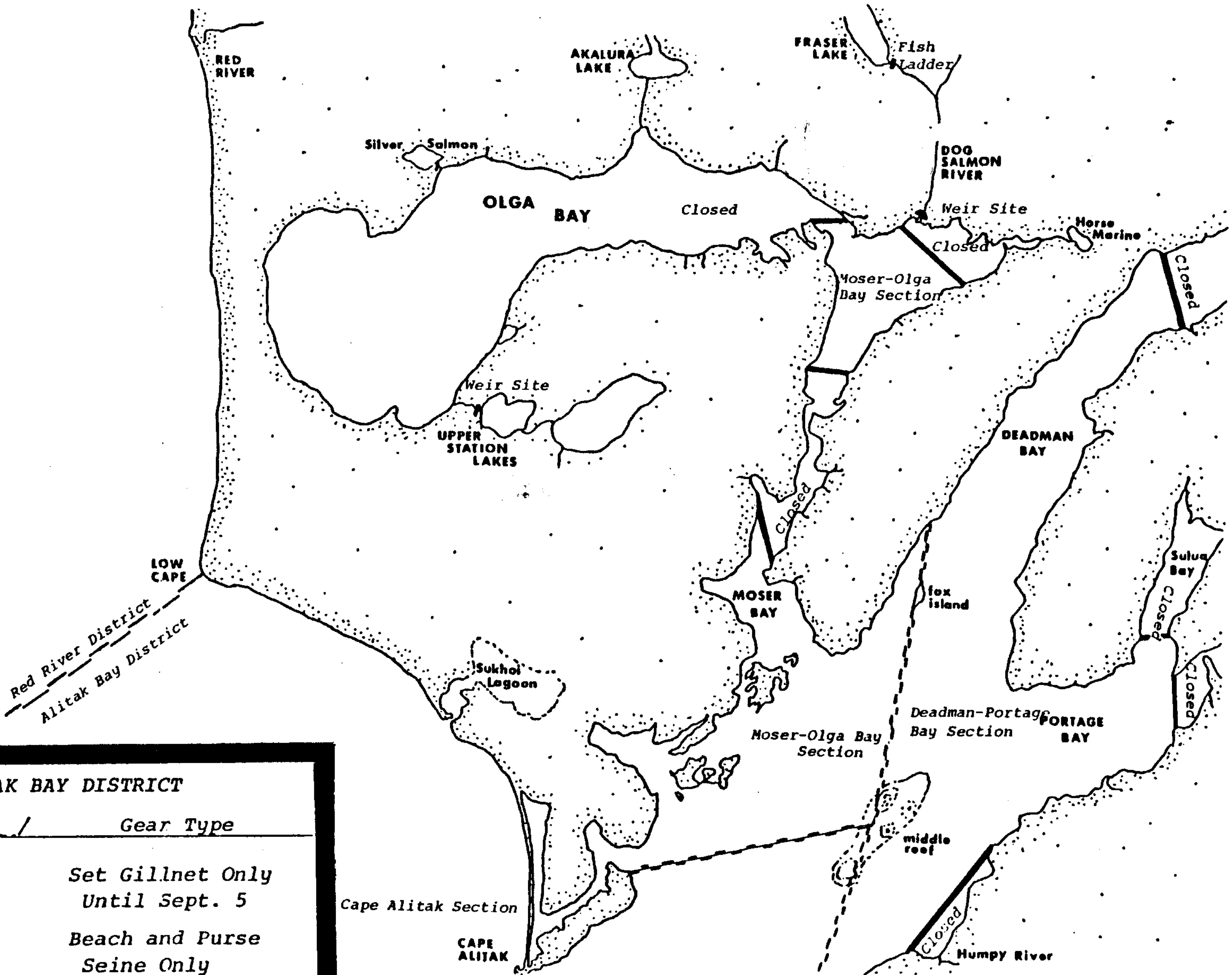


Figure 12. Earliest, latest, and computer average time-of-entry curves from the Chignik sockeye salmon runs based on adult tagging conducted from 1962-1966 (frame A); and daily stock composition estimated by SPA for the years 1978-1984 (frame B). Both frames refer to the same run. Figure taken from Marshall et al. (1987).



ALITAK BAY DISTRICT

Section	Gear Type
Moser-Olga Bay Section	Set Gillnet Only Until Sept. 5
Cape Alitak Section	Beach and Purse Seine Only
Deadman-Portage Bay Section	Beach and Purse Seine Only

Figure 13. Moser-Olga Bay Section, Cape Alitak Section, and Deadman-Portage Bay Section of the Alitak Bay District, Kodiak Island Fishery Unit. Also shown are drainages of the three principal sockeye salmon stocks (Upper Station Lakes, Akalura Lake, and Fraser Lake).

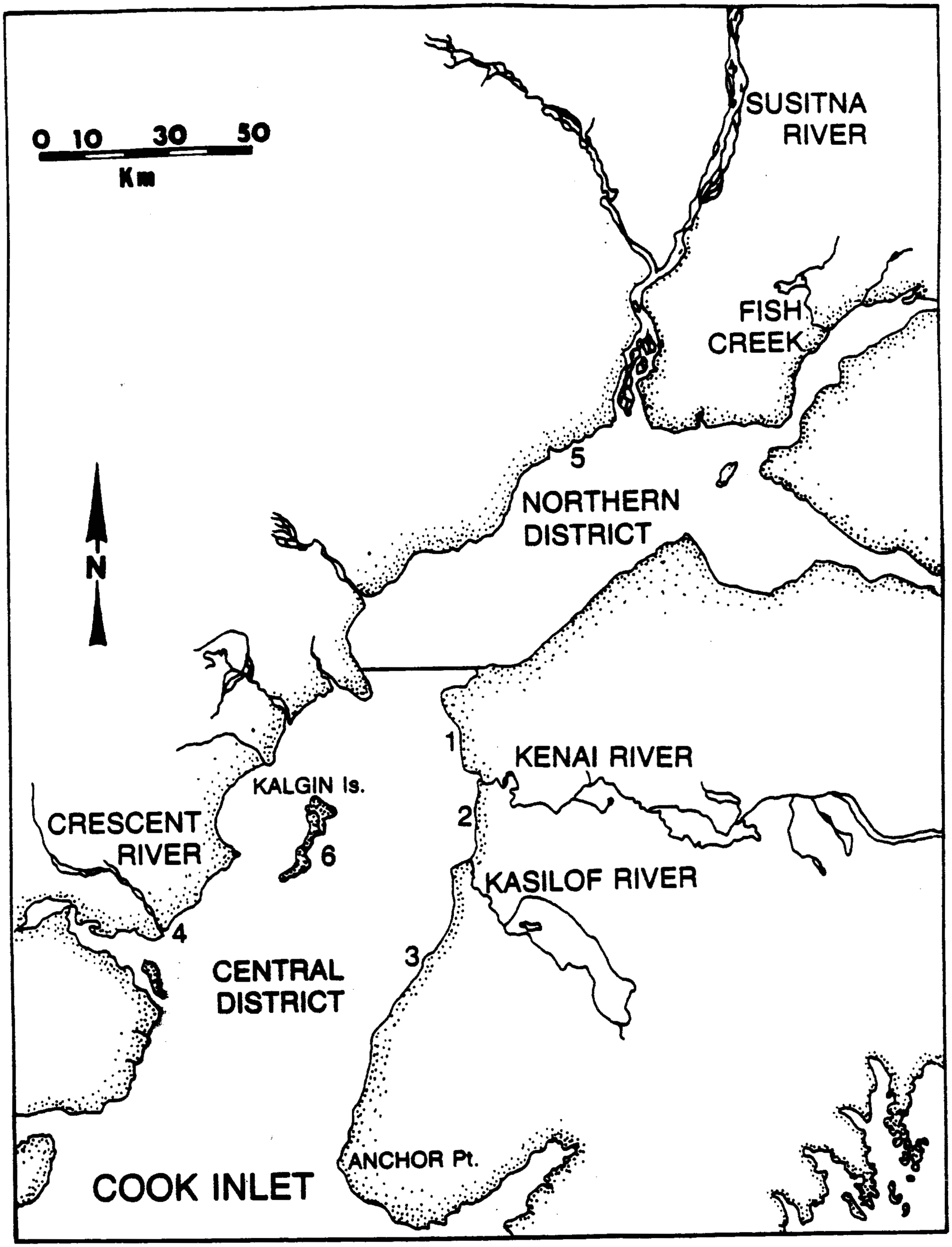


Figure 14. The upper Cook Inlet area showing the location of the fisheries and major spawning drainages of sockeye salmon. Setnet fisheries are (1) Salamatof Beach, (2) Kalifonski Beach, (3) Cohoe/Ninilchik Beach, (4) West-side, and (5) Kalgin. The driftnet fishery operates in the Central District. Figure taken from Marshall et al. (1987).

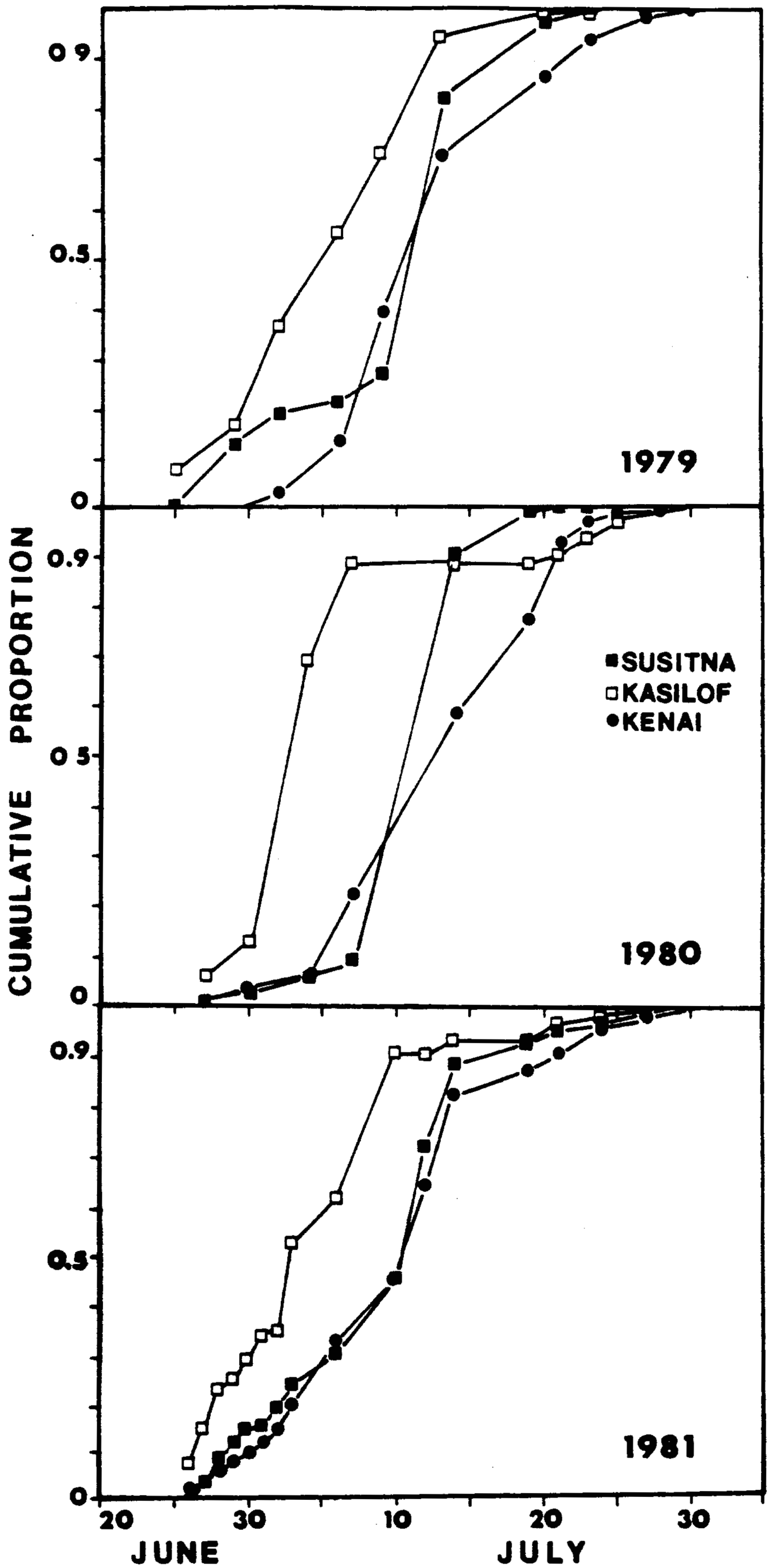


Figure 15. Cumulative proportion of catch-per-unit-of-effort in the drift fishery of age 1.3 sockeye salmon bound for the Kenai, Kasilof, and Susitna Rivers 1979-1981. Boat-days is the unit of effort. Figure taken from Marshall et al. (1987).

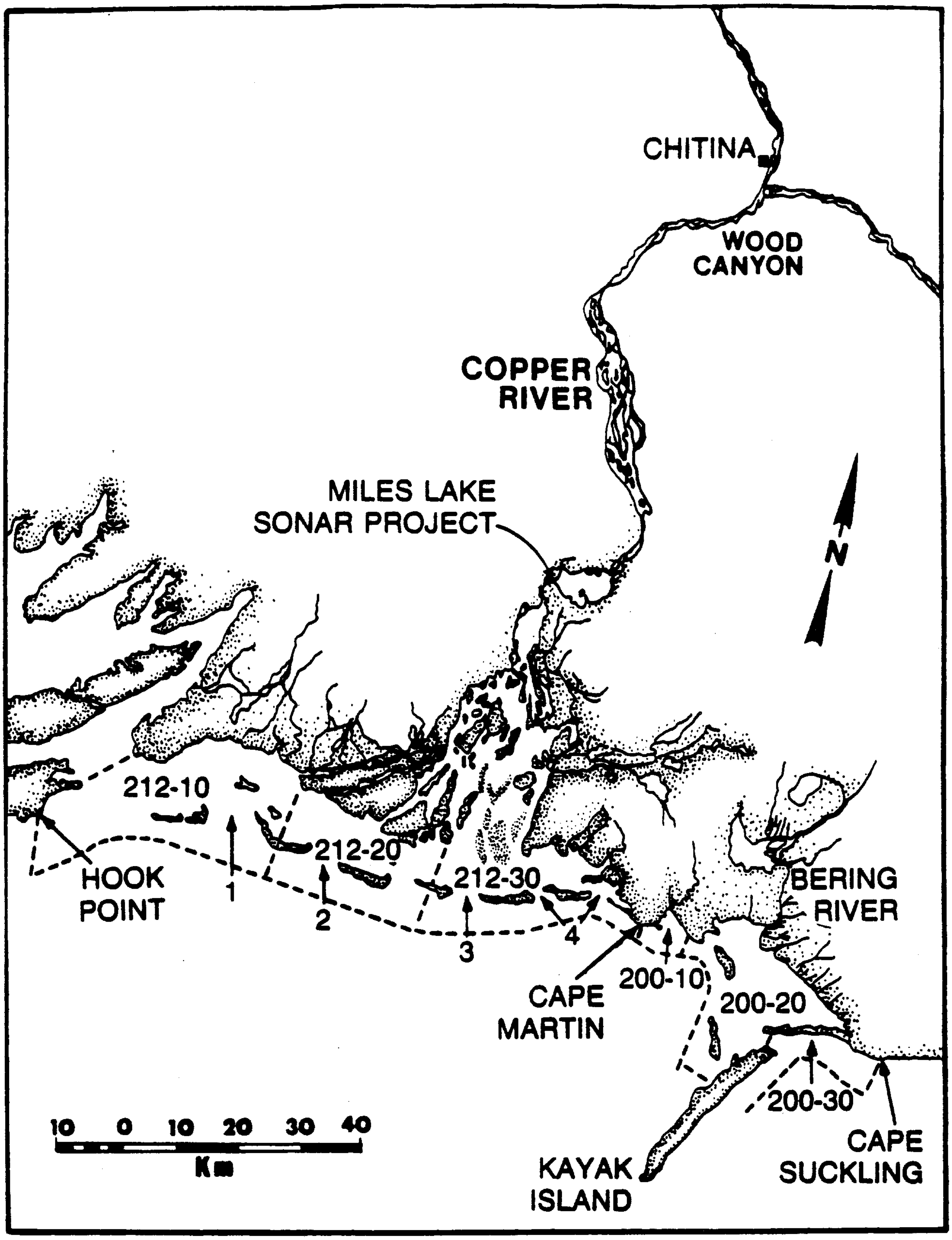


Figure 16. The Copper-Bering Rivers area showing the locations of the fisheries and major sockeye salmon spawning drainages. Channels of the Copper River Delta fishing district (212-10 through 212-30) and (1) Egg Island, (2) Pete Dahl, (3) Kokinhenik, and (4) Softuk. Figure taken from Marshall et al. (1987).

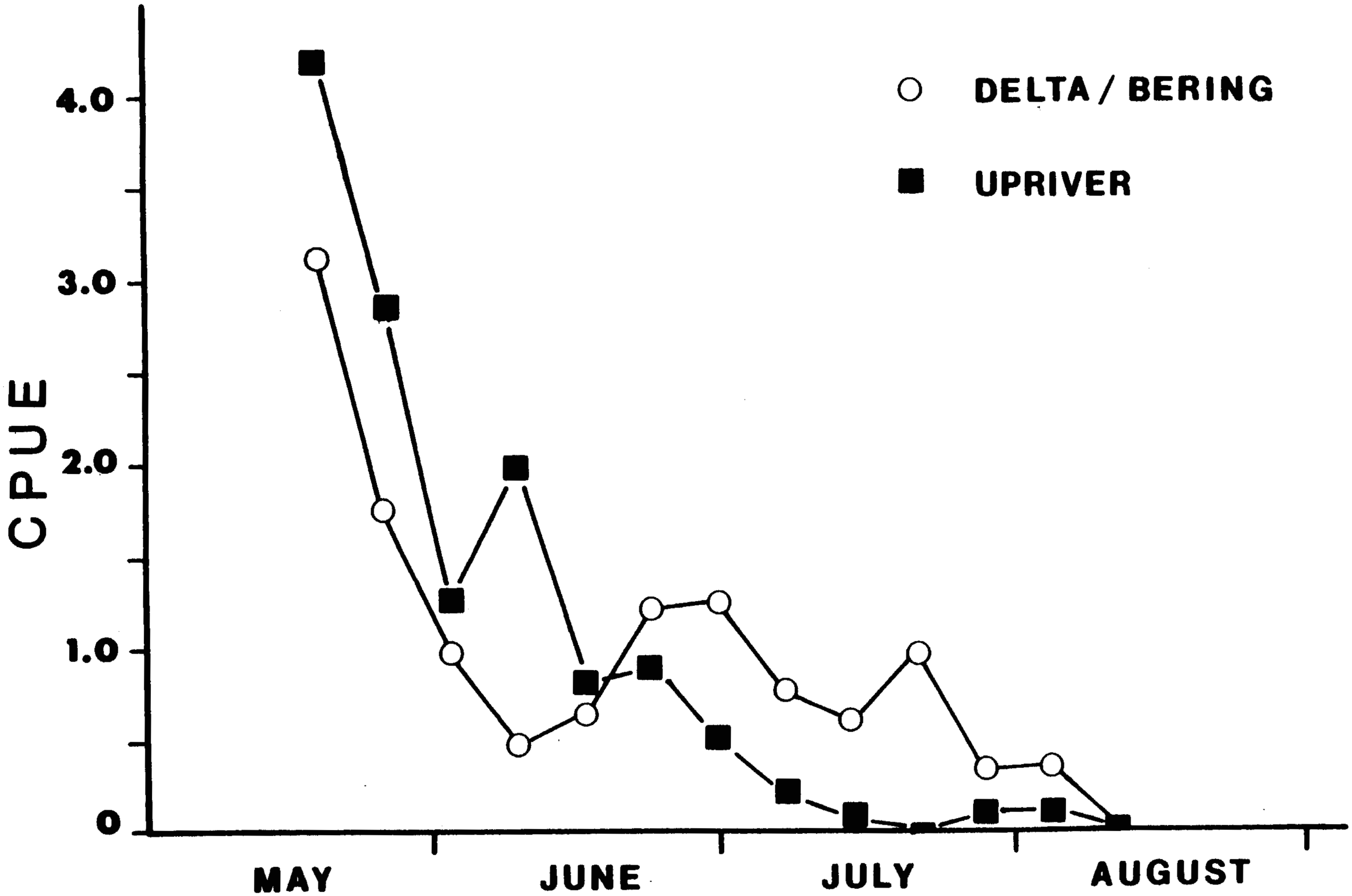


Figure 17. Catch-per-unit-of-effort of Upriver and Delta origins of salmon aged 1.3 in the Copper River District fishery during 1982. Boat days are unit of effort. Figure taken from Marshall et al. (1987).

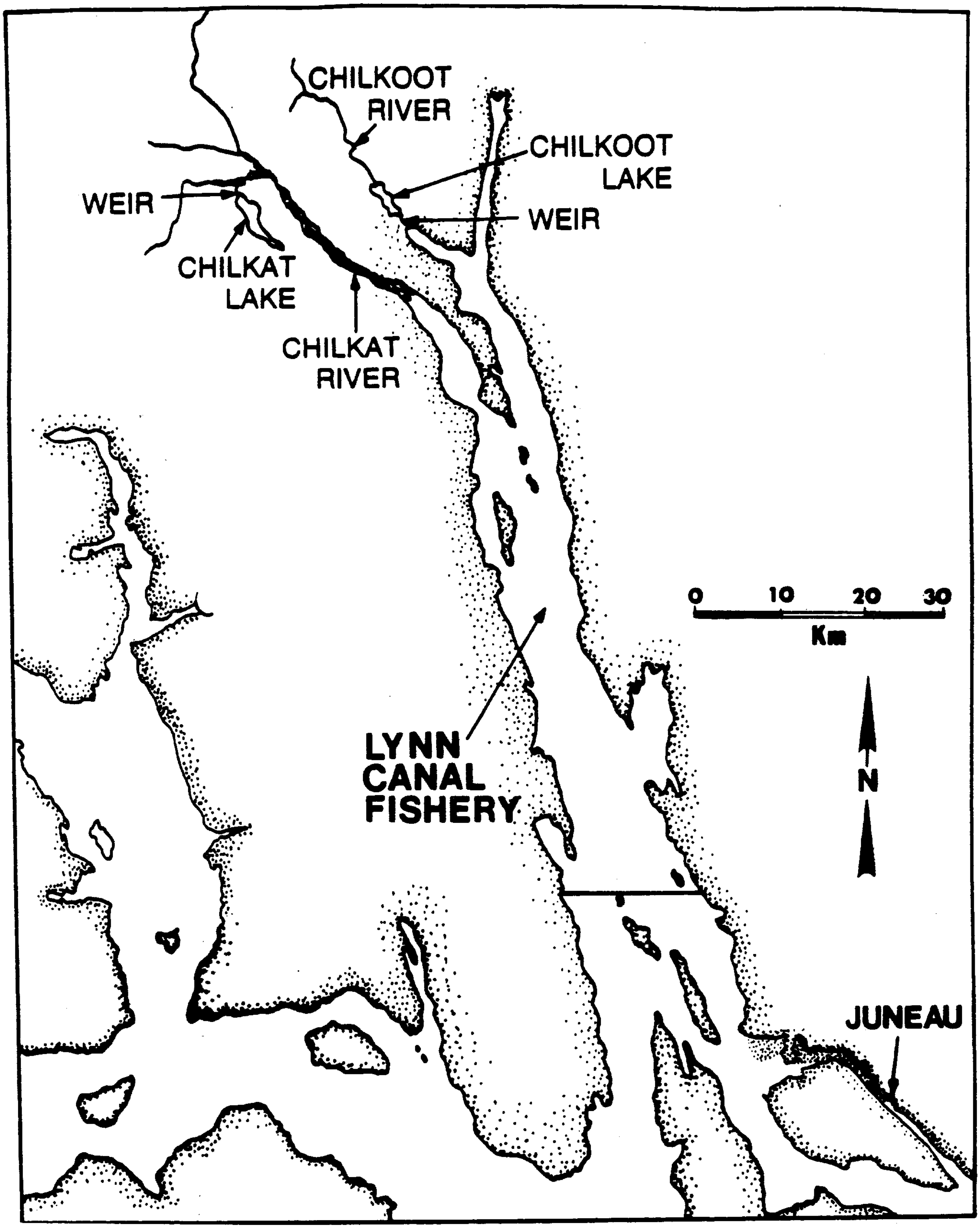


Figure 18. The Lynn Canal area showing the location of the fishery and the major sockeye salmon spawning drainages. Figure taken from Marshall et al. (1987).

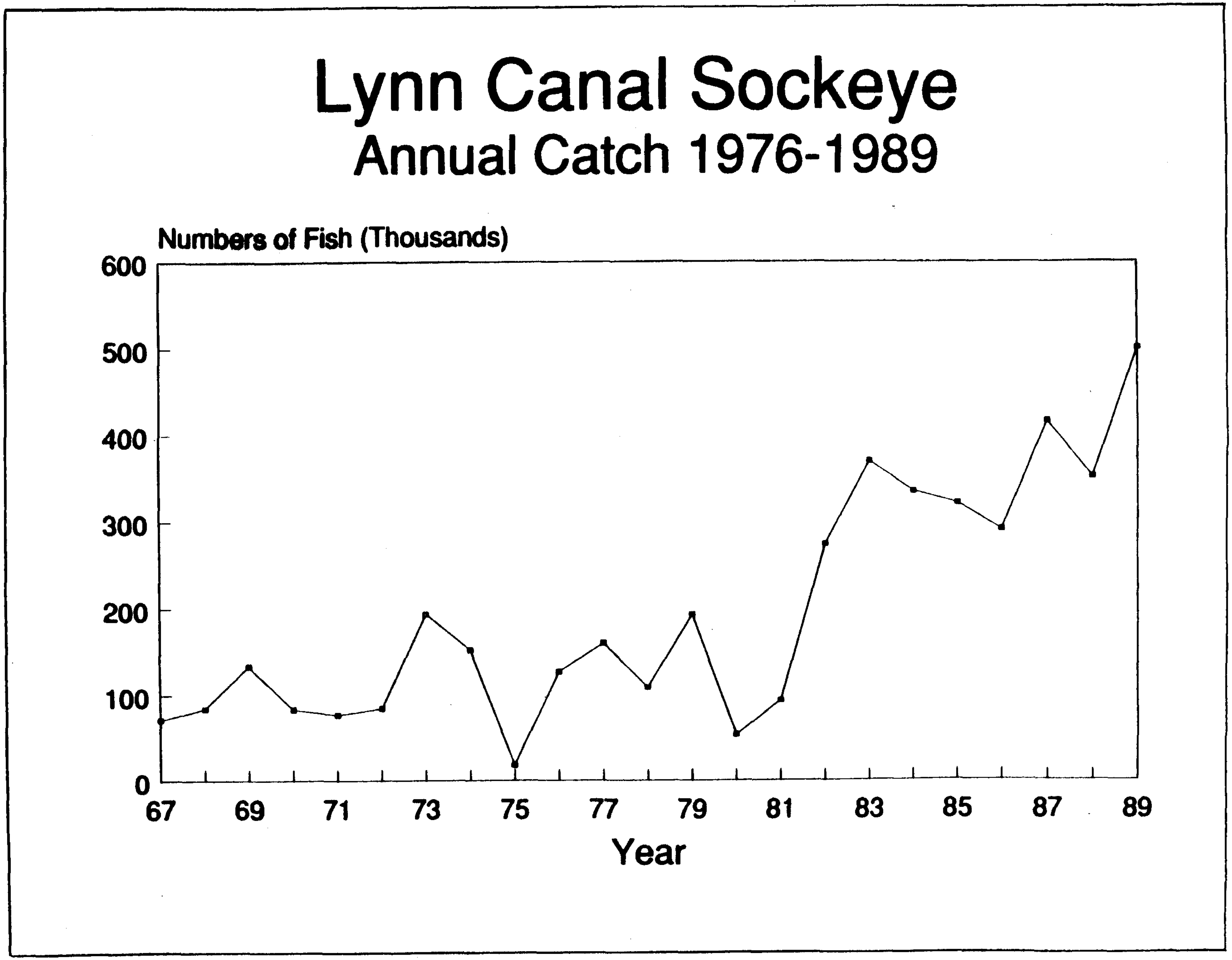


Figure 19. Catches of sockeye salmon in the Lynn Canal fishery, 1976-1989.

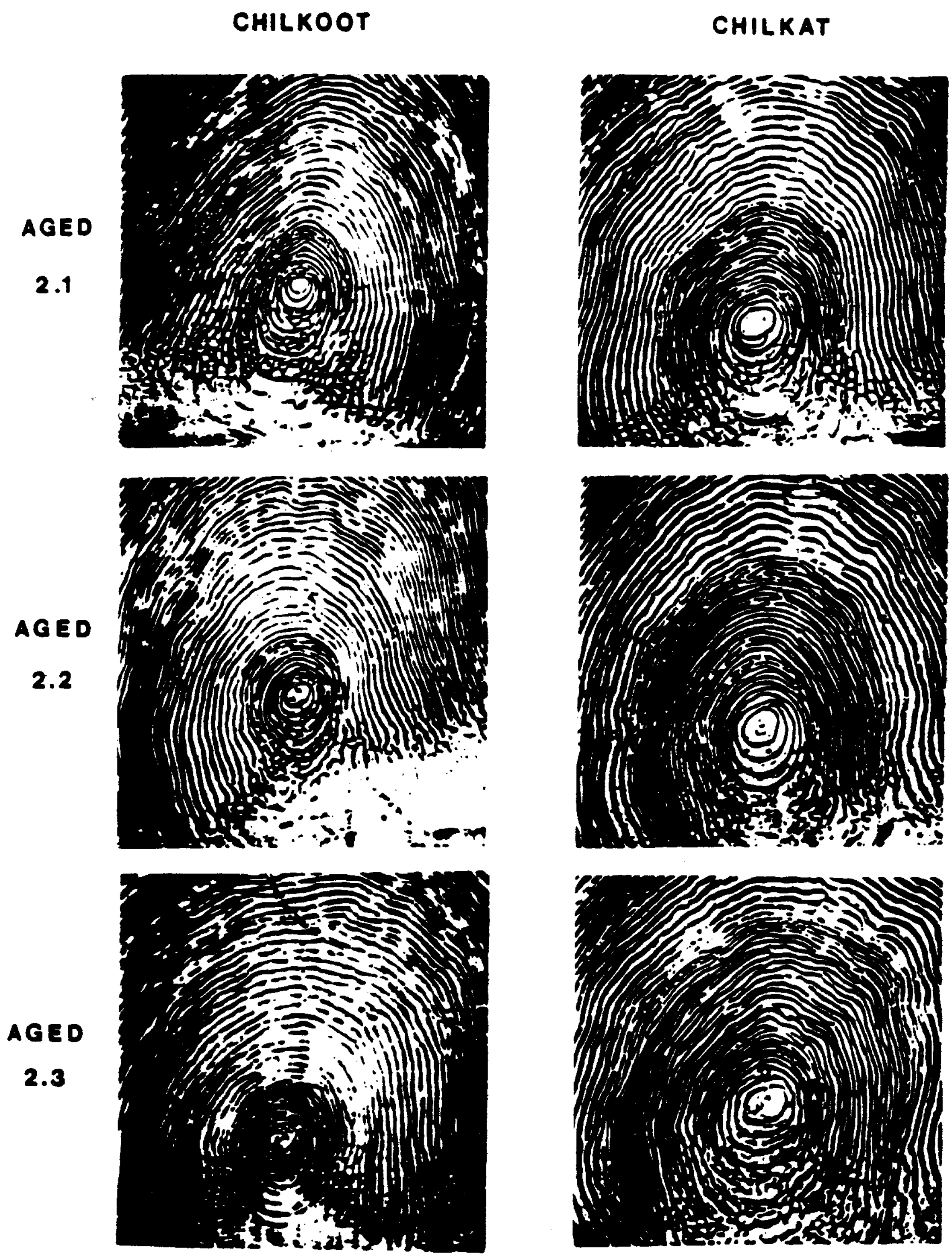


Figure 20. Representative scales from sockeye salmon, ages 2.1, 2.2, and 2.3 taken from the Chilkoot Lake and Chilkat Lake spawning areas.

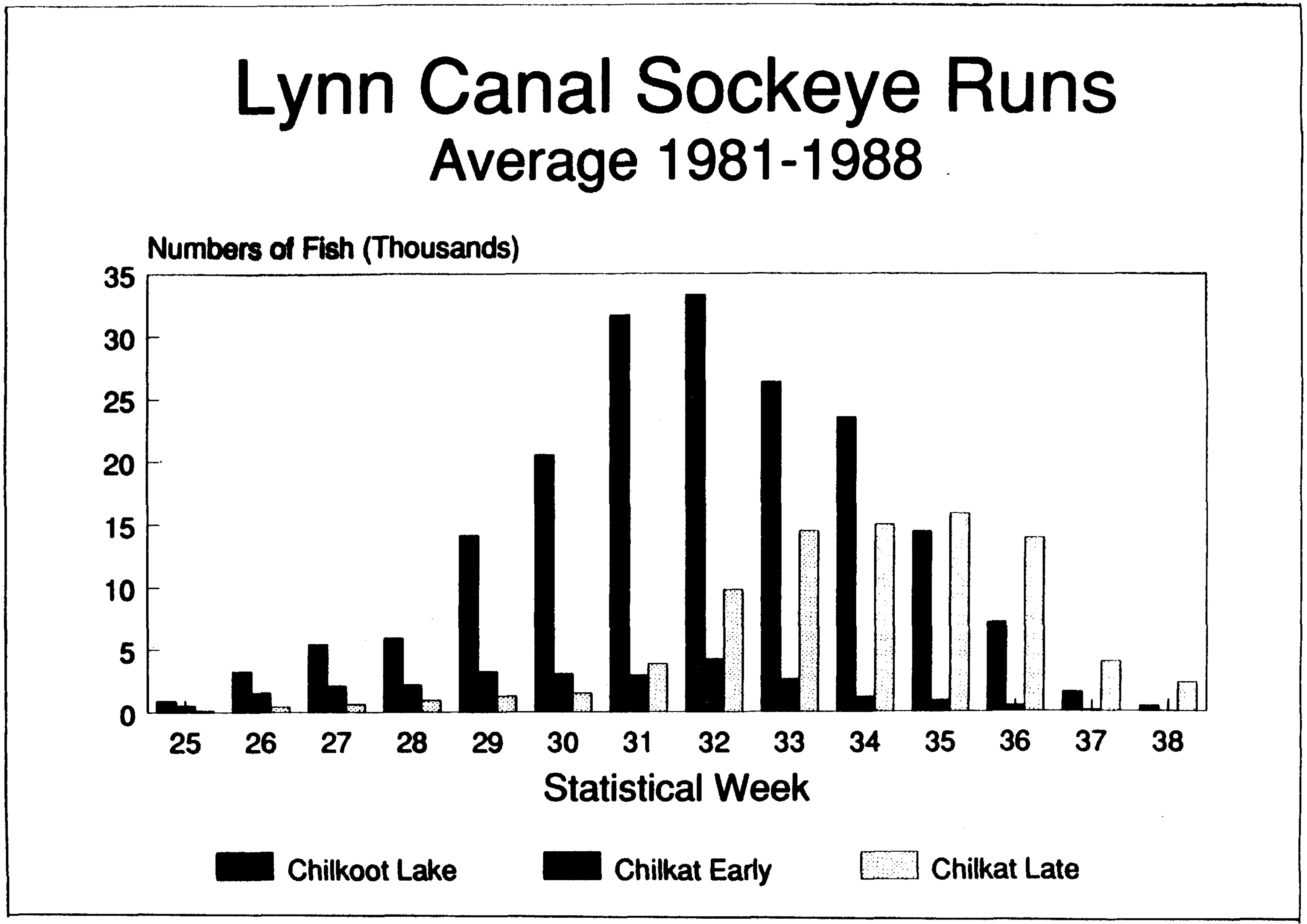


Figure 21. Run timing through the Lynn Canal fishery averaged over the years 1981-1988, for Chilkoot, early Chilkat, and late Chilkat sockeye salmon stocks.

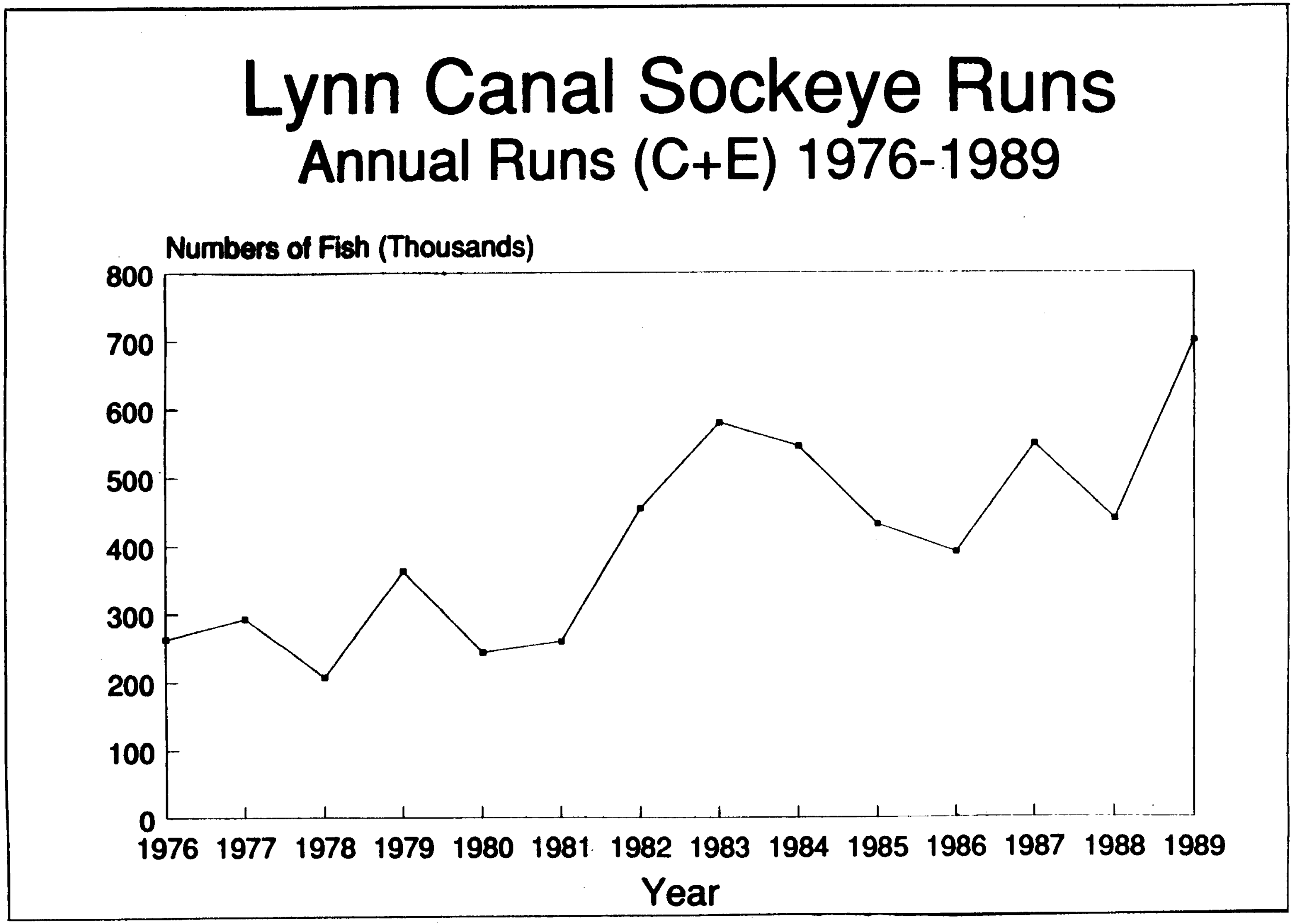


Figure 22. Run magnitude (catch + escapement) of sockeye salmon in Lynn Canal, 1976-1989.

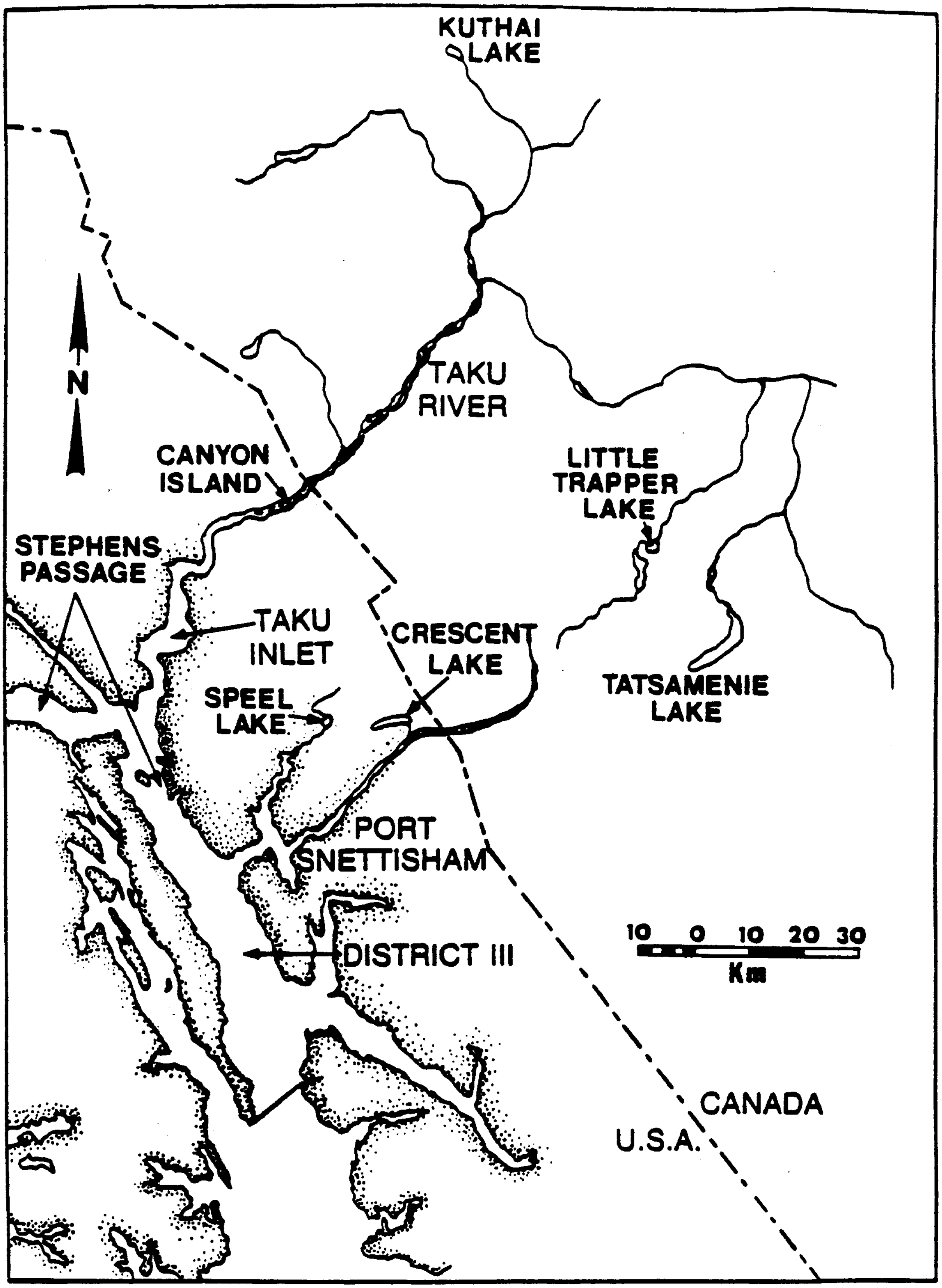


Figure 23. The Taku-Snettisham area showing the major spawning drainages for sockeye salmon in the Taku River (Kuthai Lake, Little Trapper Lake, Tatsamenie Lake, and the mainstem Taku River) and Snettisham area (Speel Lake and Crescent Lake). Figure taken from Marshall et al. (1987).

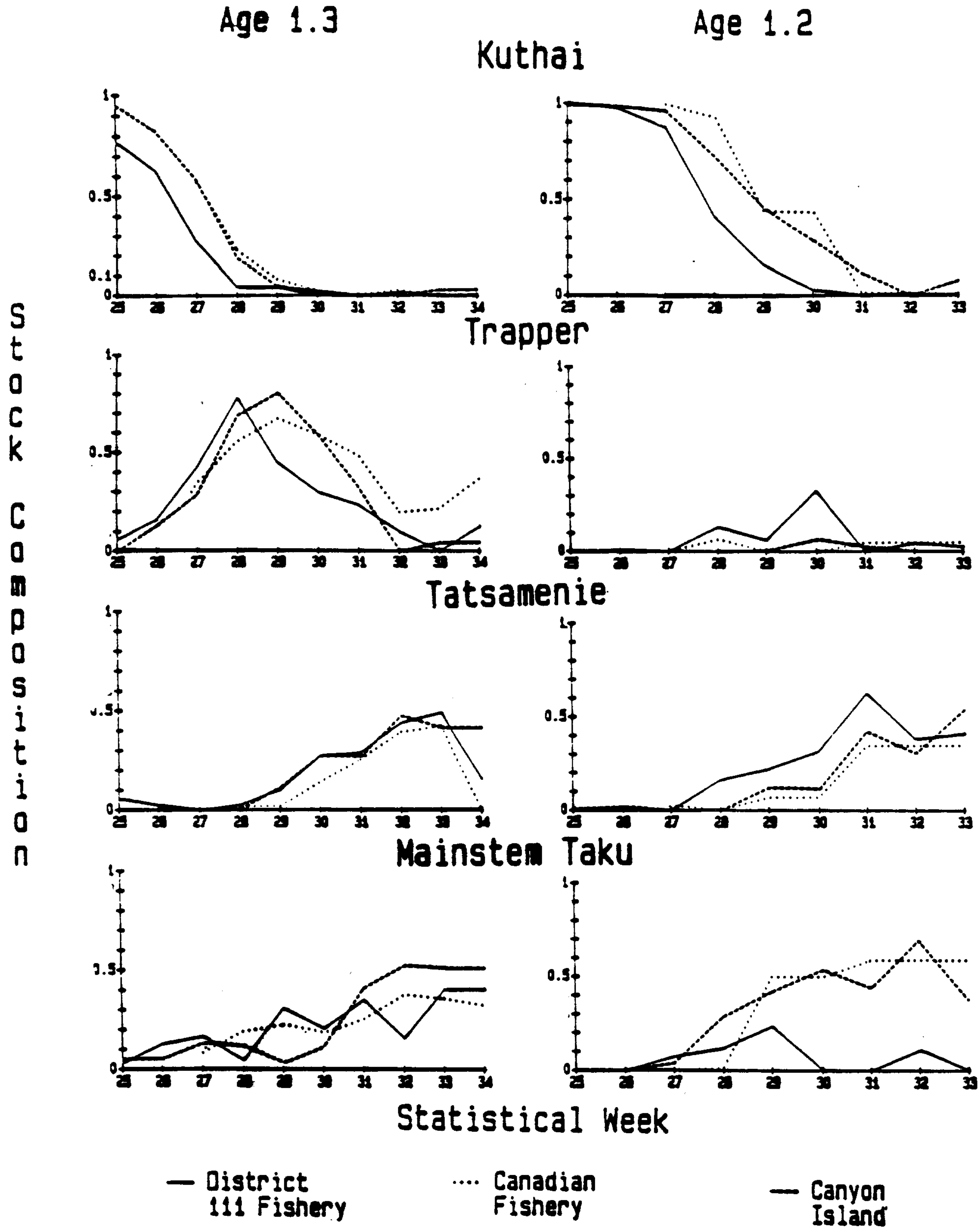


Figure 24. Estimates of the percent contributions of age 1.3 and 1.2 Taku River stock groupings to the traditional District 111 fishery, Canyon Island fishwheel catches, and the Canadian Taku River fishery, 1986. Figure taken from McGregor and Walls (1987).

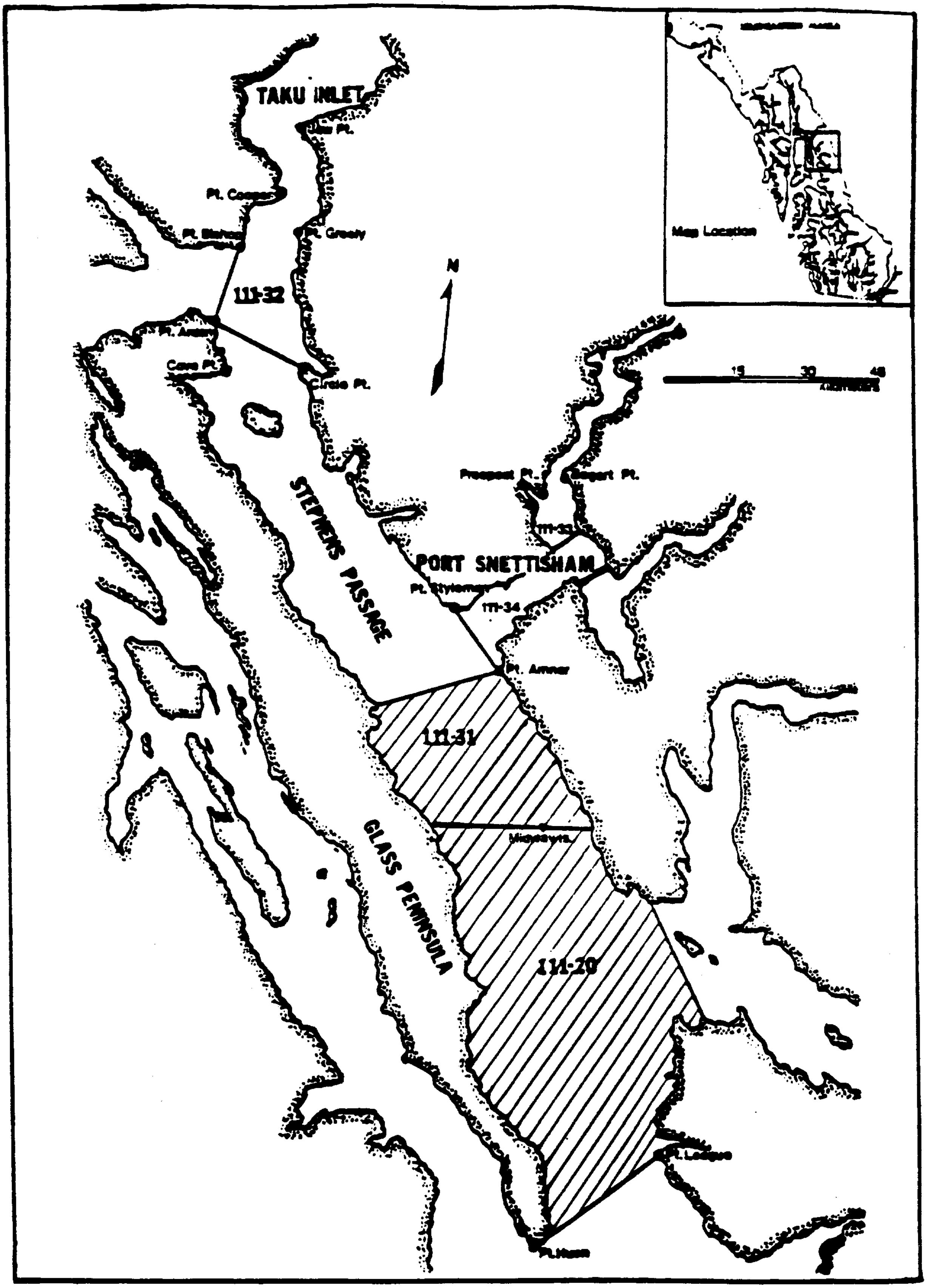


Figure 25. District 111 gillnet fishing area, with subdistricts. Shaded area represents the portion of the district open in the supplemental fishery. Figure taken from McGregor and Walls (1987).

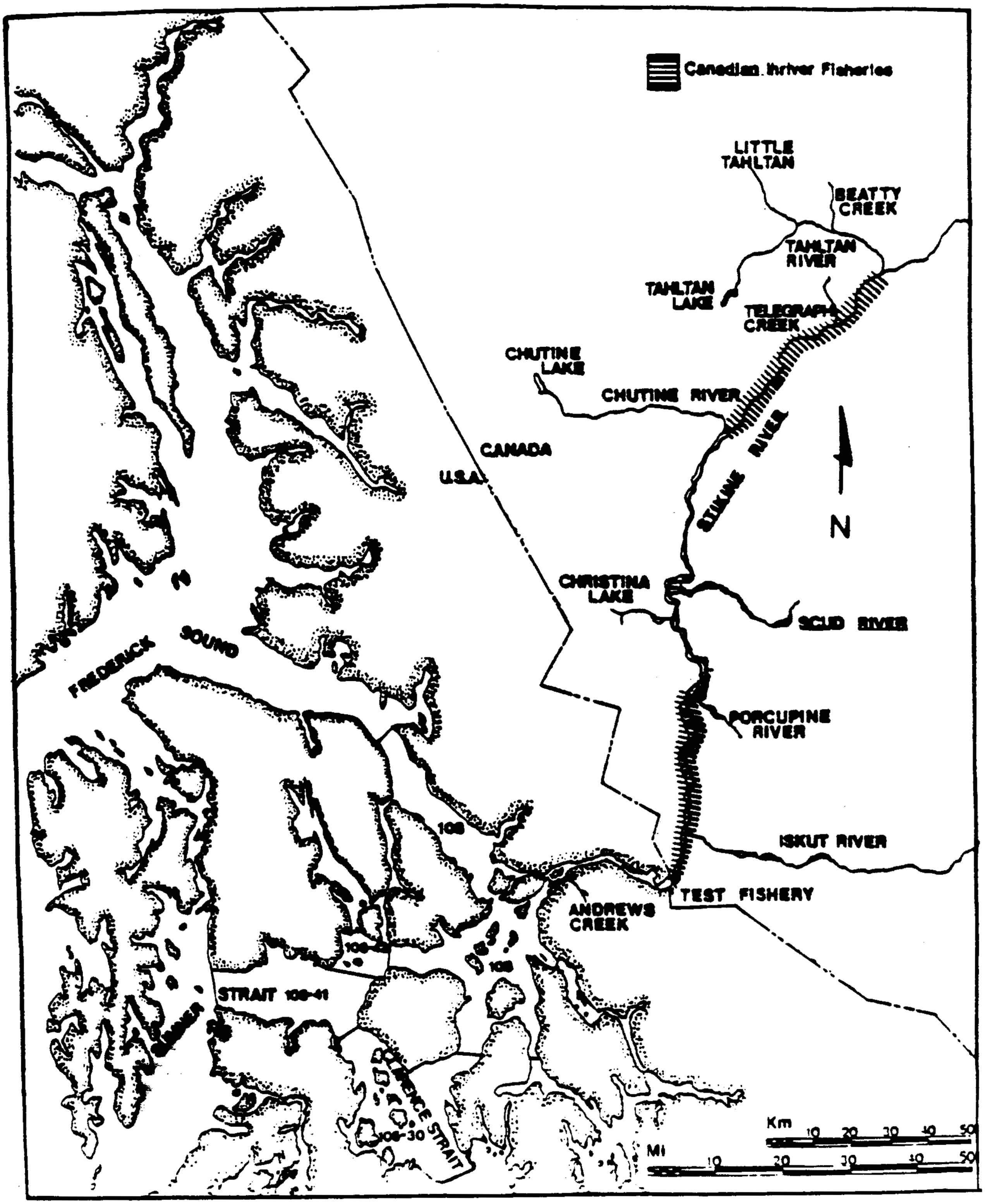


Figure 26. The transboundary Stikine River, major tributaries, and the fishery areas (District 106, District 108, and Canadian in-river fishery area). Figure taken from Jensen and Frank (1989).

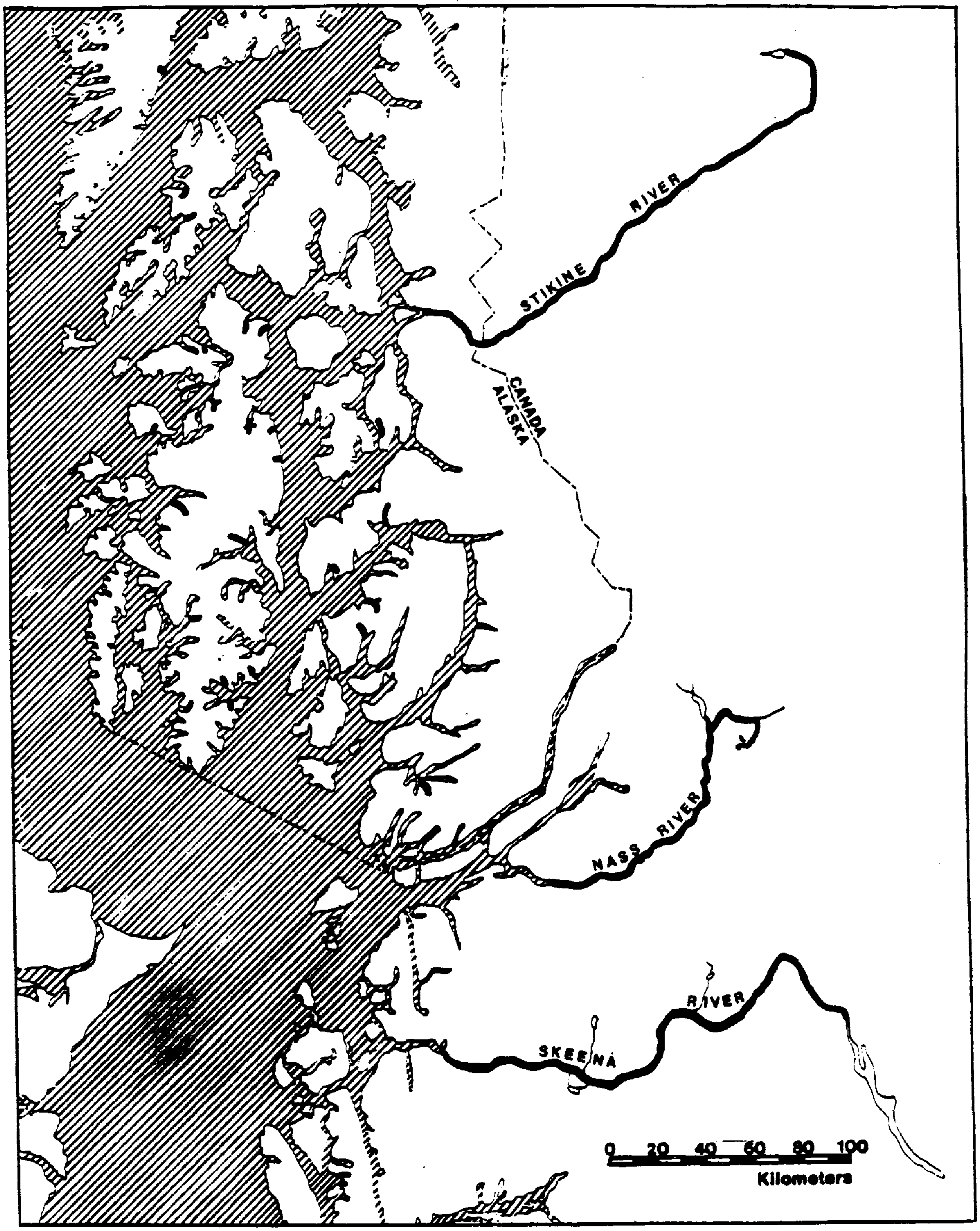


Figure 27. Major sockeye salmon spawning drainages in the northern boundary area. Stock groupings include Alaska coastal lakes, Nass and Skeena River, and Stikine River.

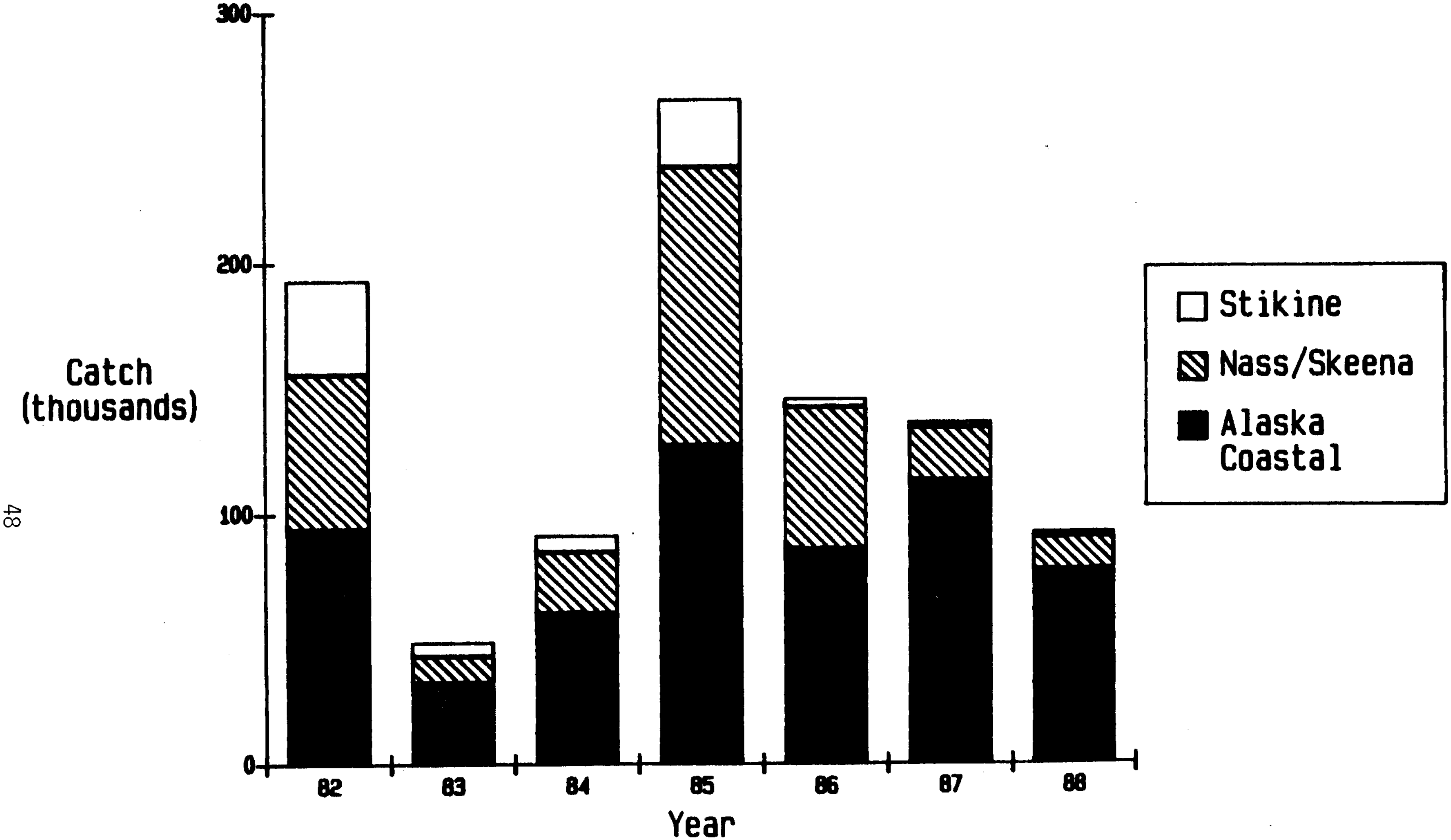


Figure 28. Stock composition, in terms of fish originating in Stikine River, Alaska coastal lakes, and Nass-Skeena River, of catches of sockeye salmon from District 106, 1982-1988. Data taken from Oliver (1988).

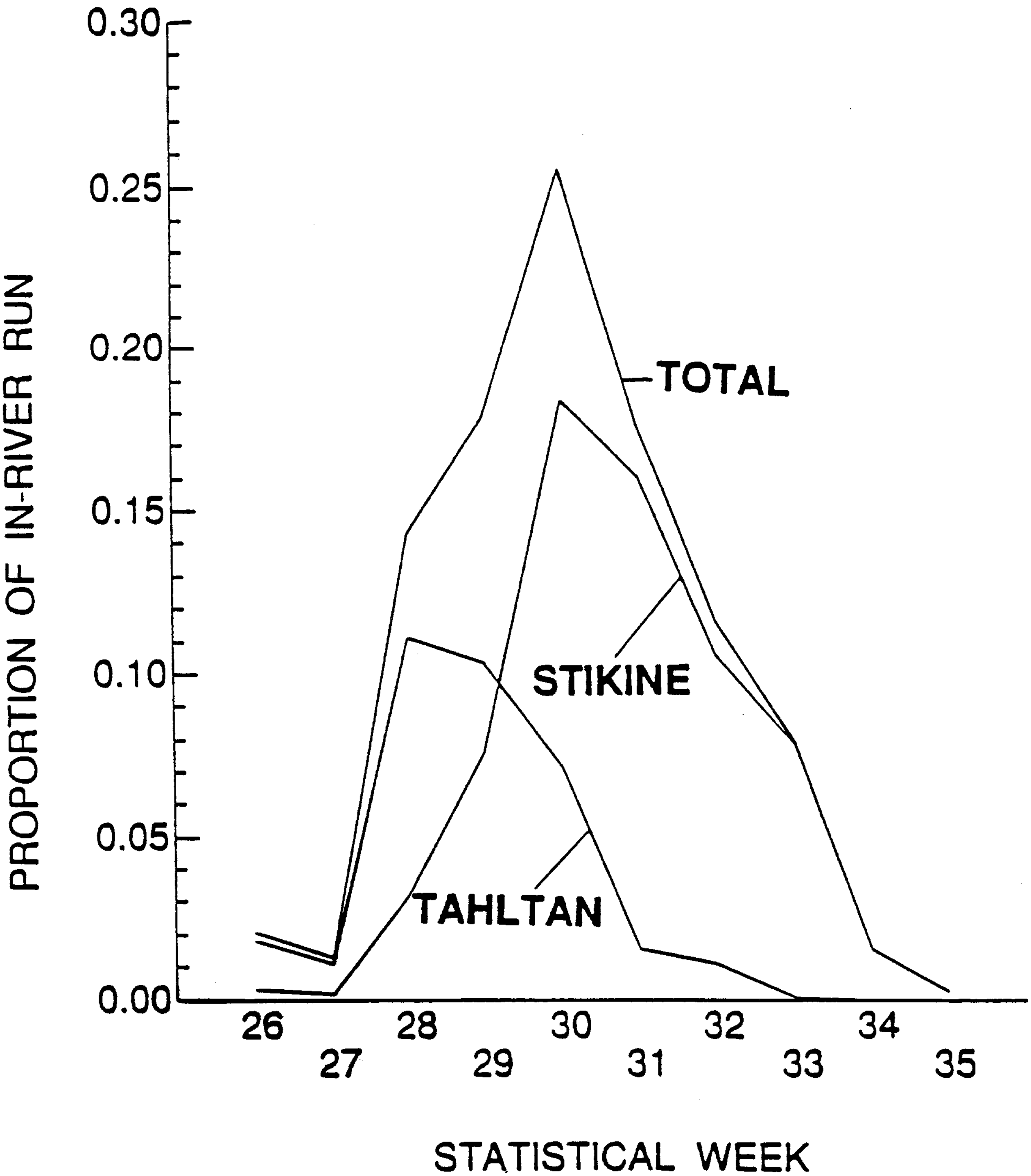


Figure 29. Migratory timing of the Tahltan and Stikine sockeye stock groups as indicated by the weekly proportion of total stock group CPUE in the Stikine River test fishery, 1987. Figure taken from Jensen and Frank (1987).

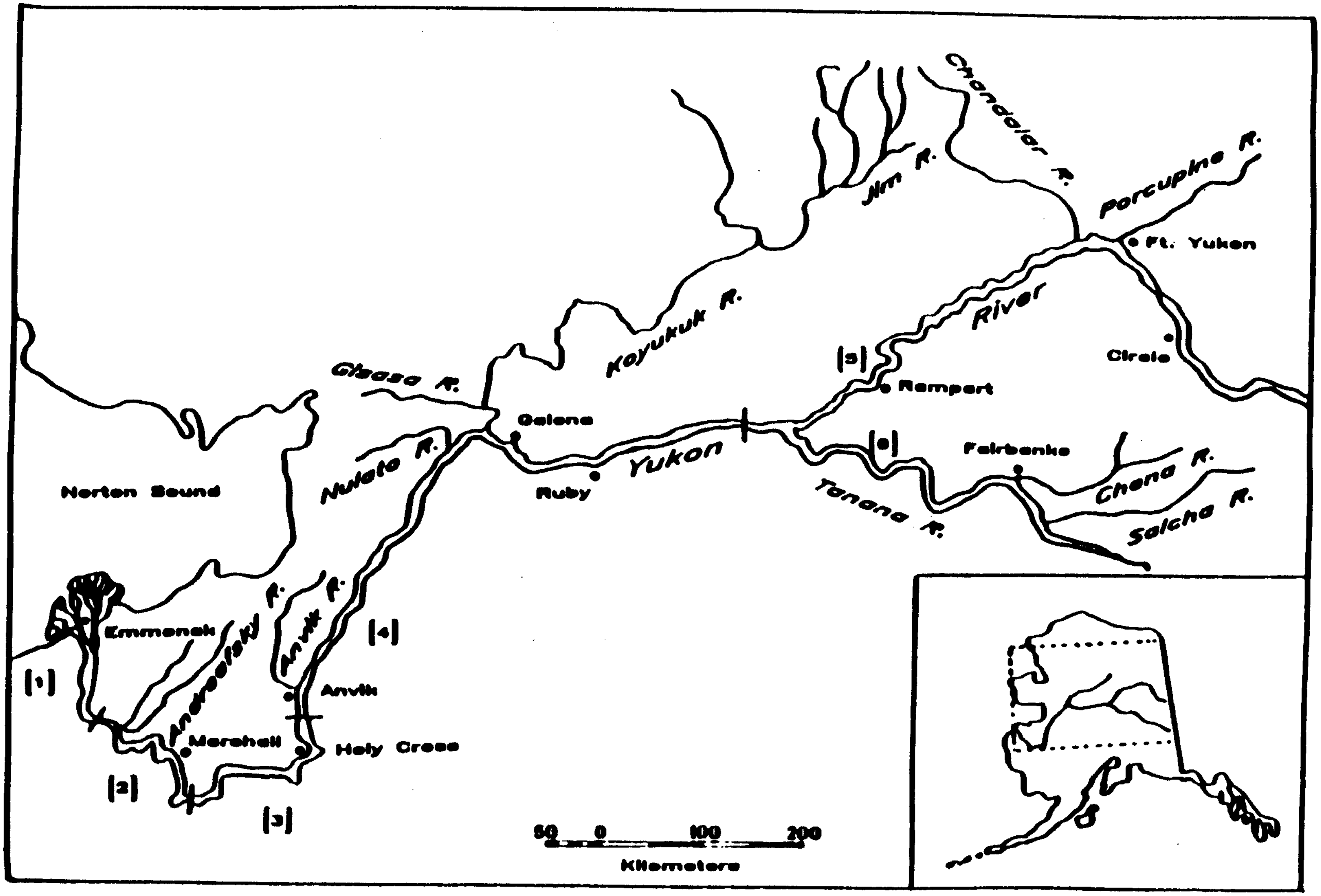


Figure 30. Alaskan portion of the Yukon River drainage showing the six regulatory districts and the major spawning tributaries for the lower and middle runs of chinook salmon. Figure taken from Brannian (1989).

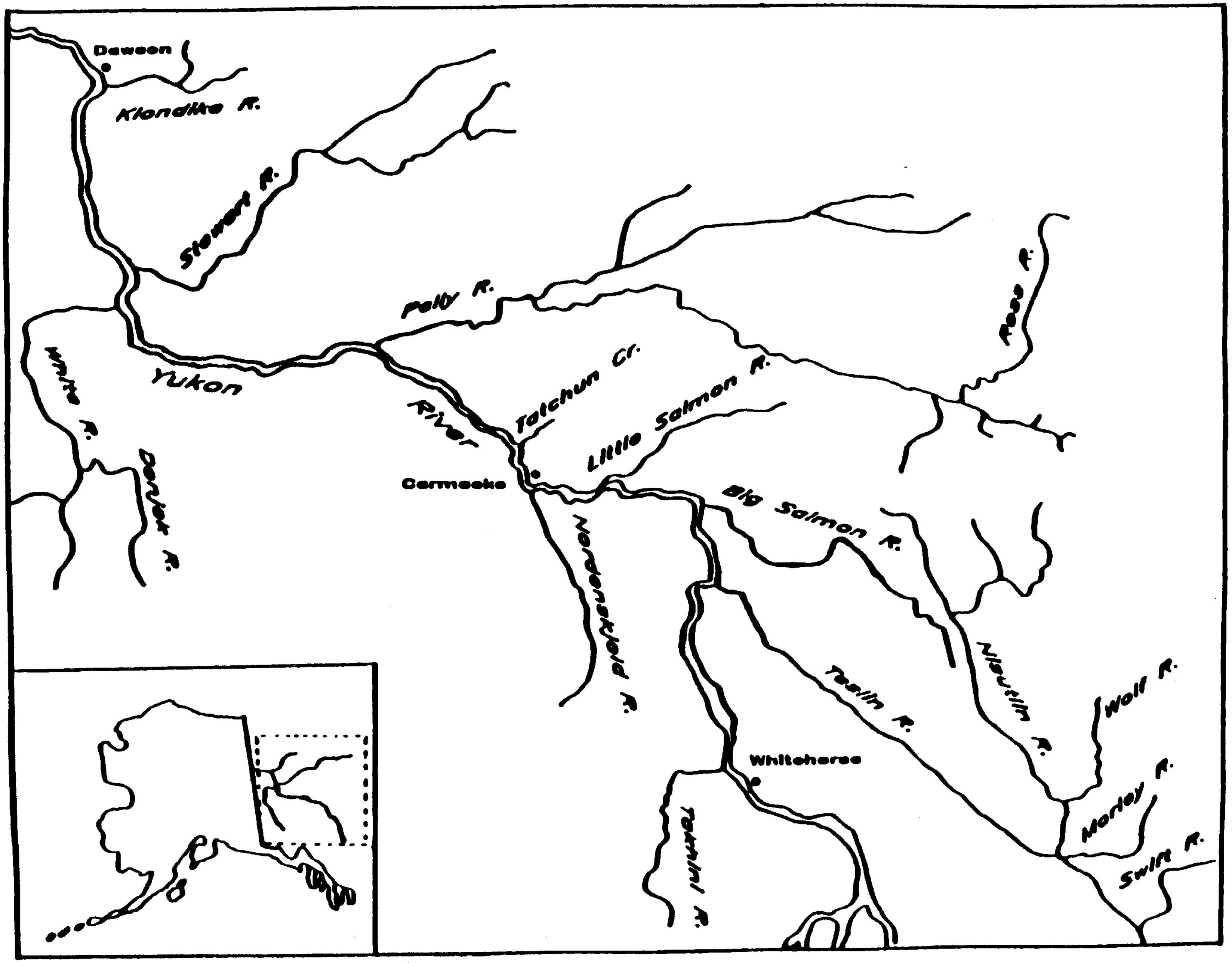


Figure 31. Canadian portion of the Yukon River drainage showing the major spawning tributaries for the upper run of chinook salmon. Figure taken from Brannian (1989).

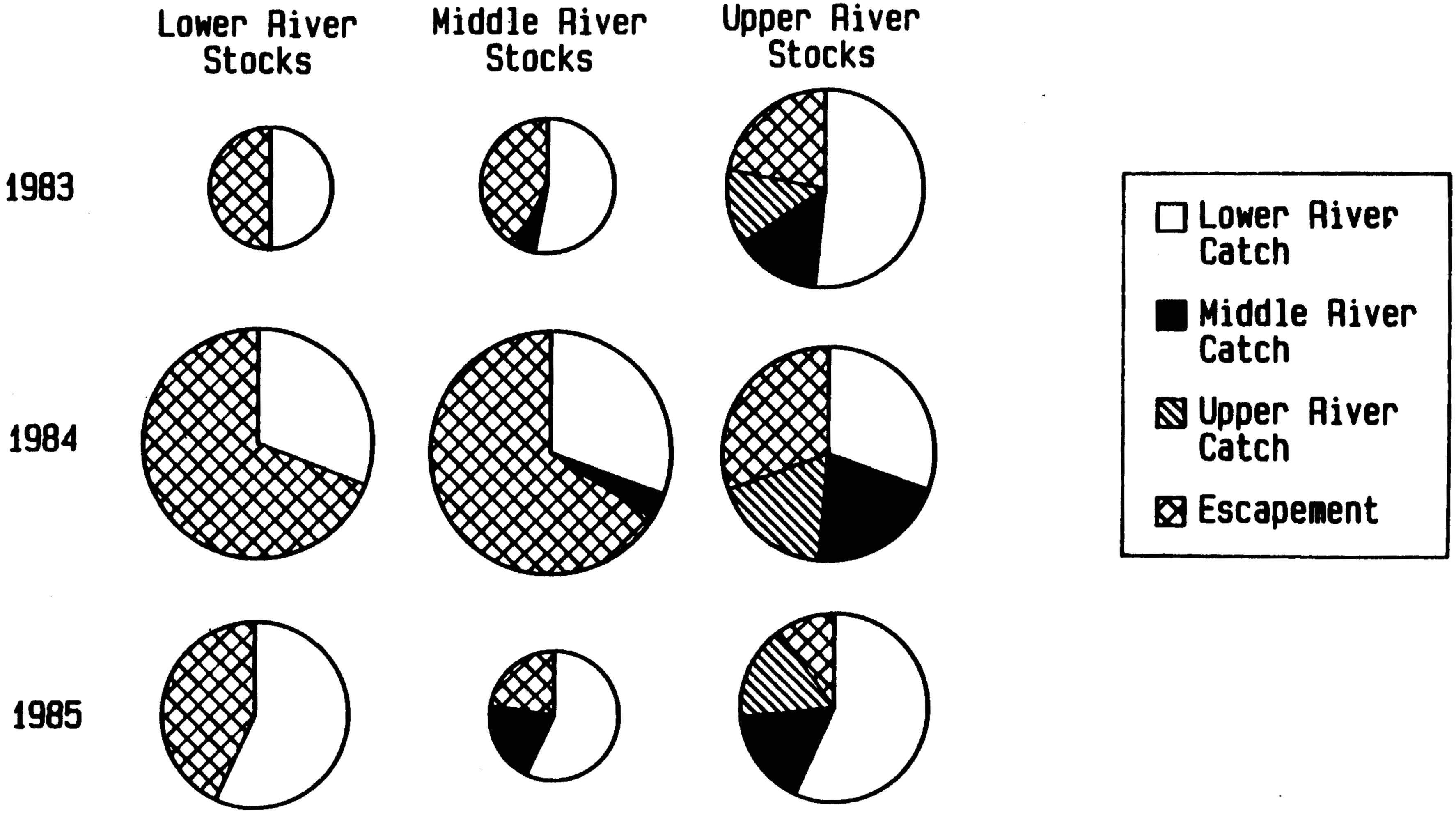


Figure 32. Reconstruction of the run (catches in the lower, middle, and upper river fishing areas and escapement) for the lower, middle, and upper river stocks of chinook salmon in the Yukon River. Relative area of pie charts scaled to relative catch magnitude for respective area of the river and year. Data taken from Brannian (1989).

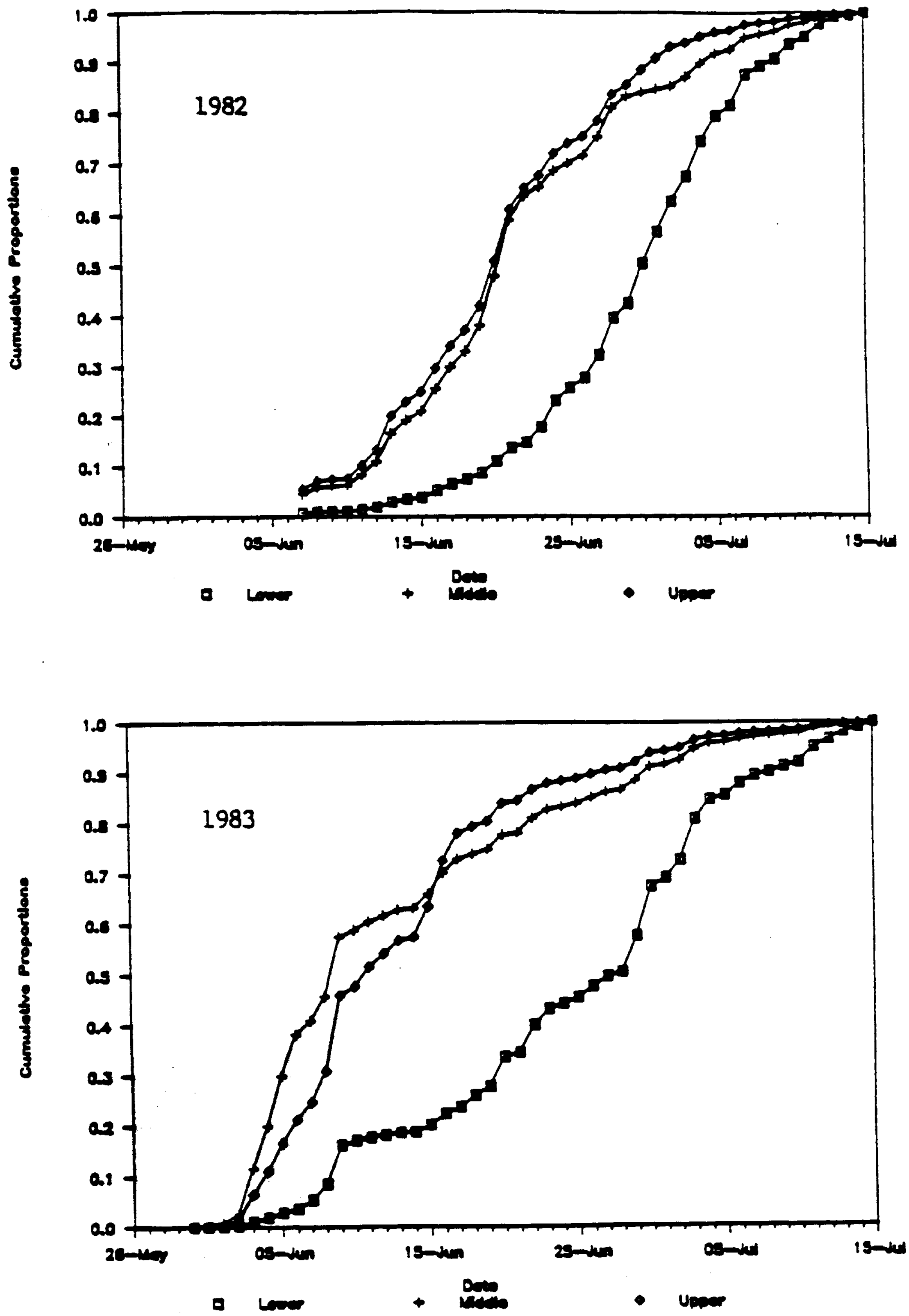


Figure 33. Cumulative proportions of chinook salmon CPUE by date and run (lower, middle, and upper) for the lower Yukon River test fishery for 1982 (top panel) and 1983 (bottom panel). Figure taken from Brannian (1989).

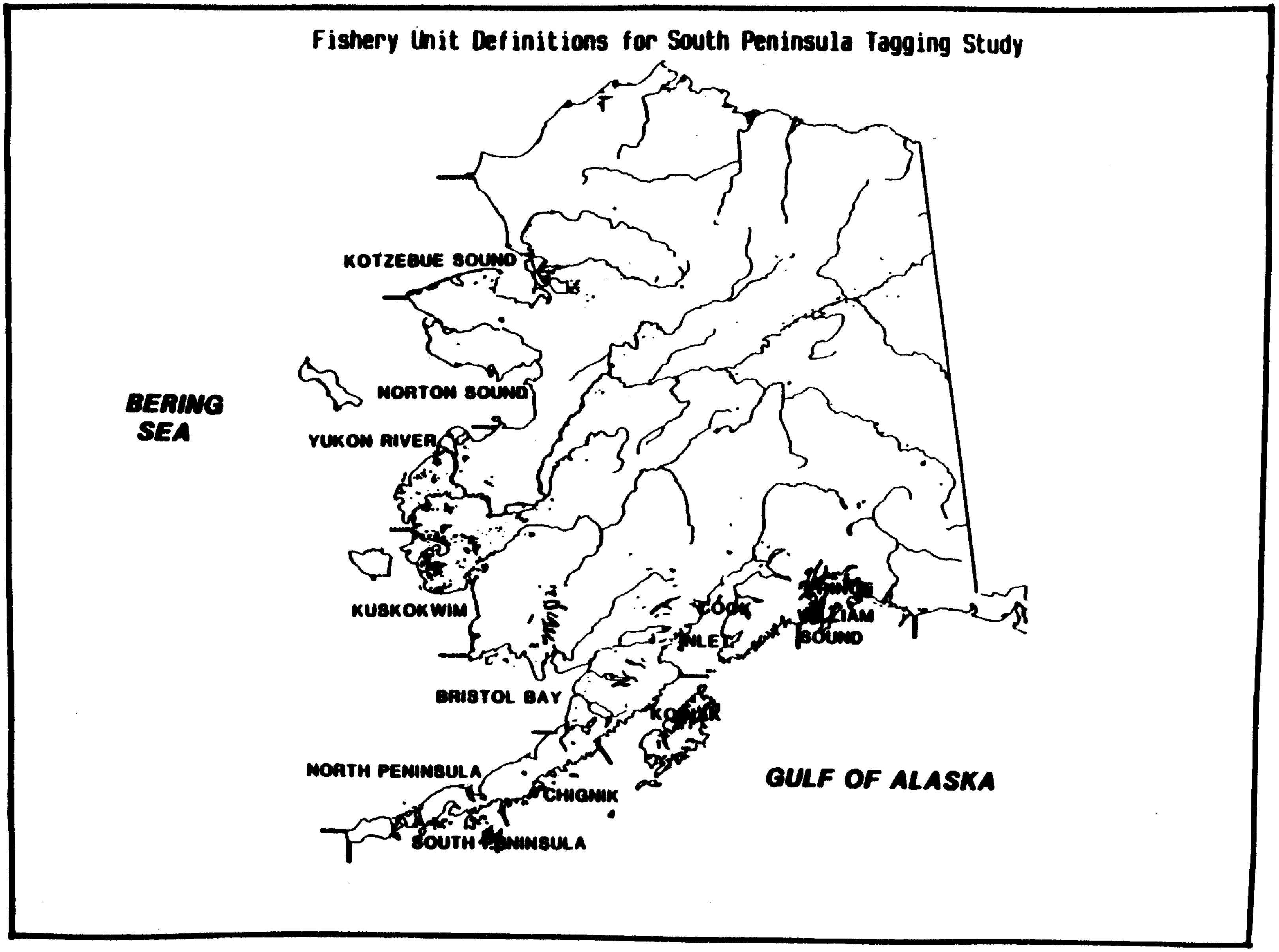


Figure 34. Fishery unit definitions by which 1987 tag recoveries, catches, and escapements were reported for western and central Alaska salmon fisheries. Figure taken from Eggers et al. (1989).

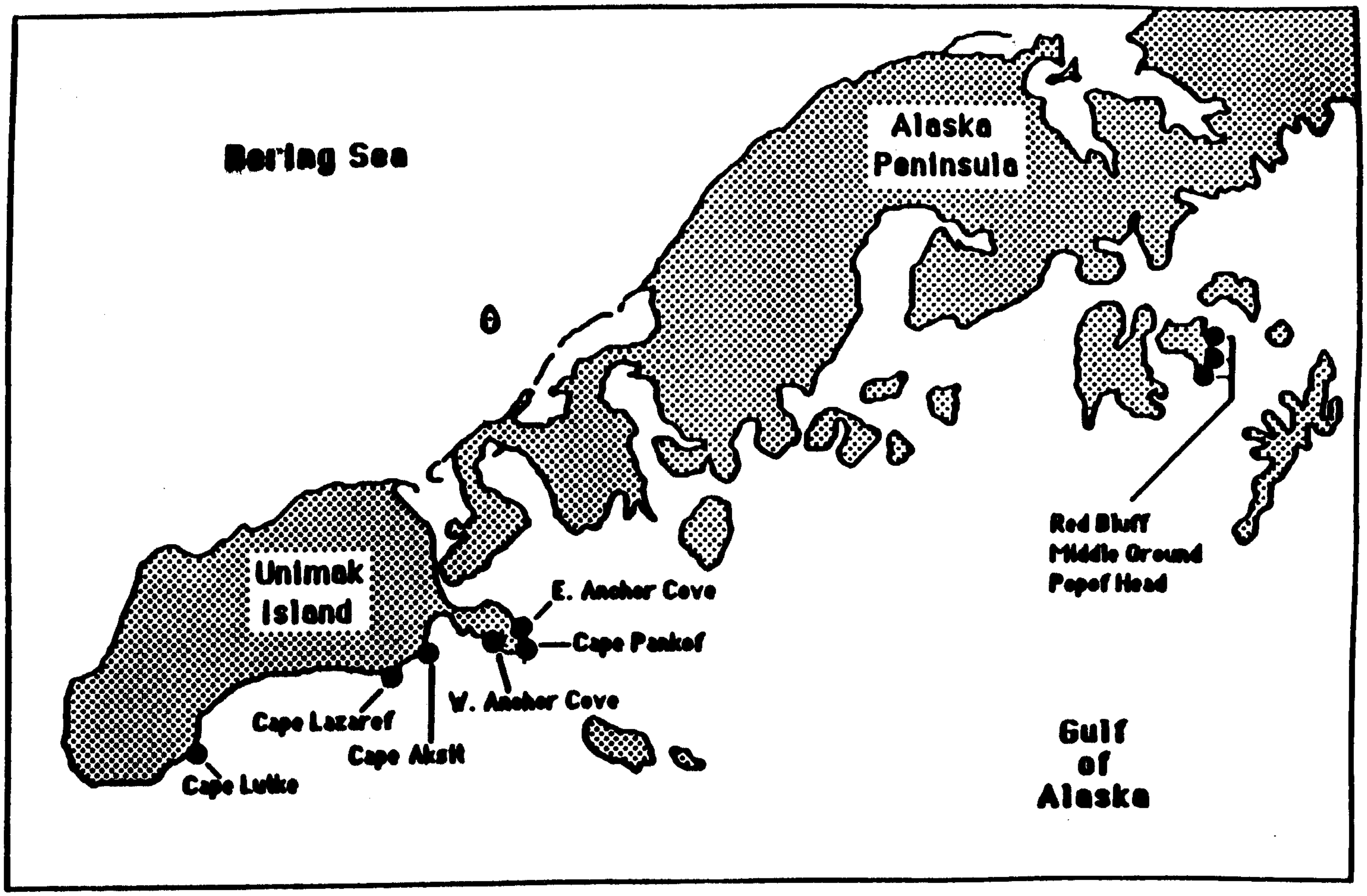


Figure 35. Tagging locations in the Unimak and Shumagin Islands area used during the South Peninsula tagging study, 1987. Figure taken from Eggers et al. (1989).

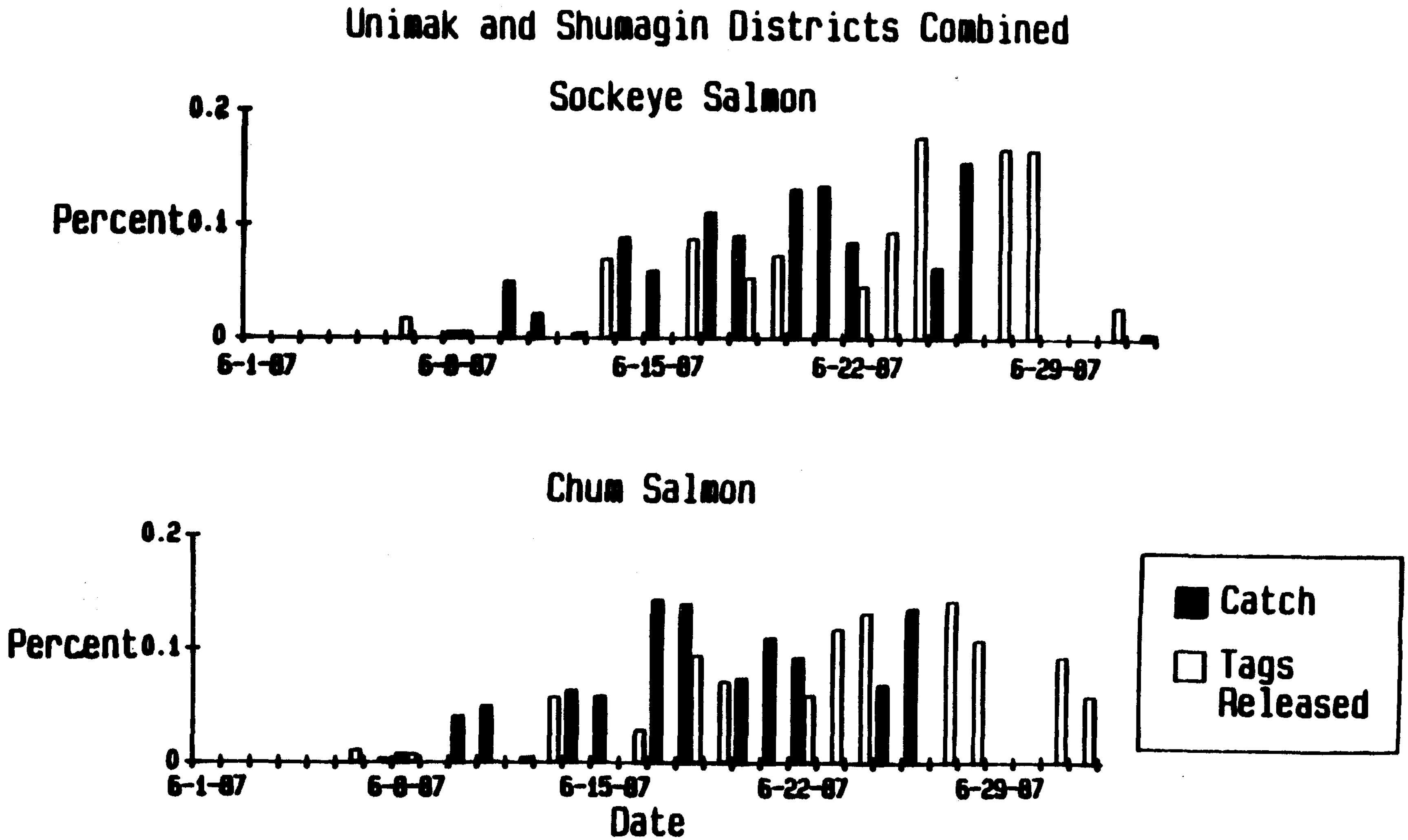


Figure 36. Timing of 1987, tag releases and catches of sockeye and chum salmon in the combined Unimak and Shumagin District. Figure taken from Eggers et al. (1989).

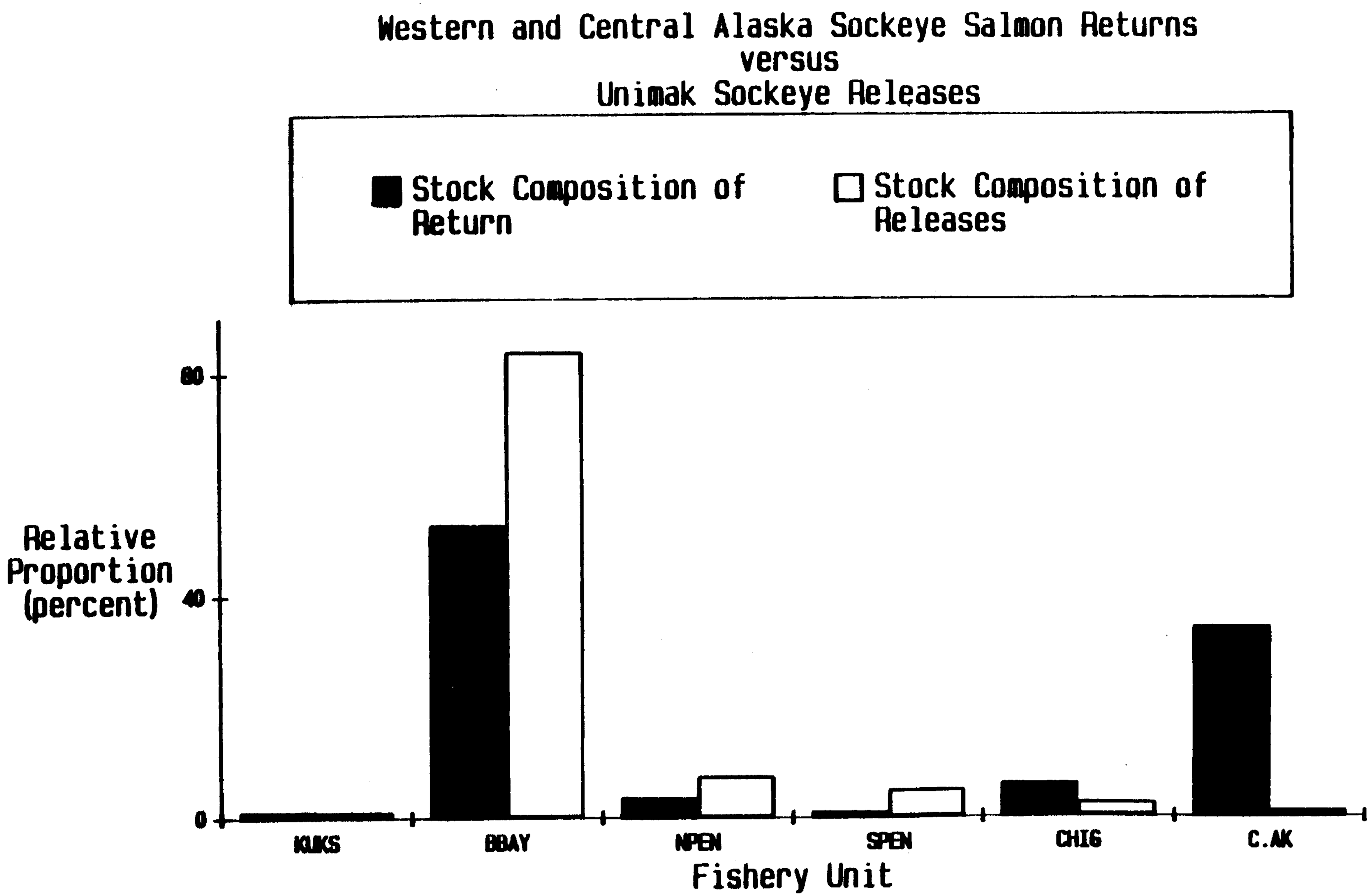


Figure 37. Stock composition (% of total return) of western and central Alaska sockeye returns versus stock composition (% of surviving releases) of Unimak releases of sockeye salmon, for various fishery units. Figure taken from Eggers et al. (1989).

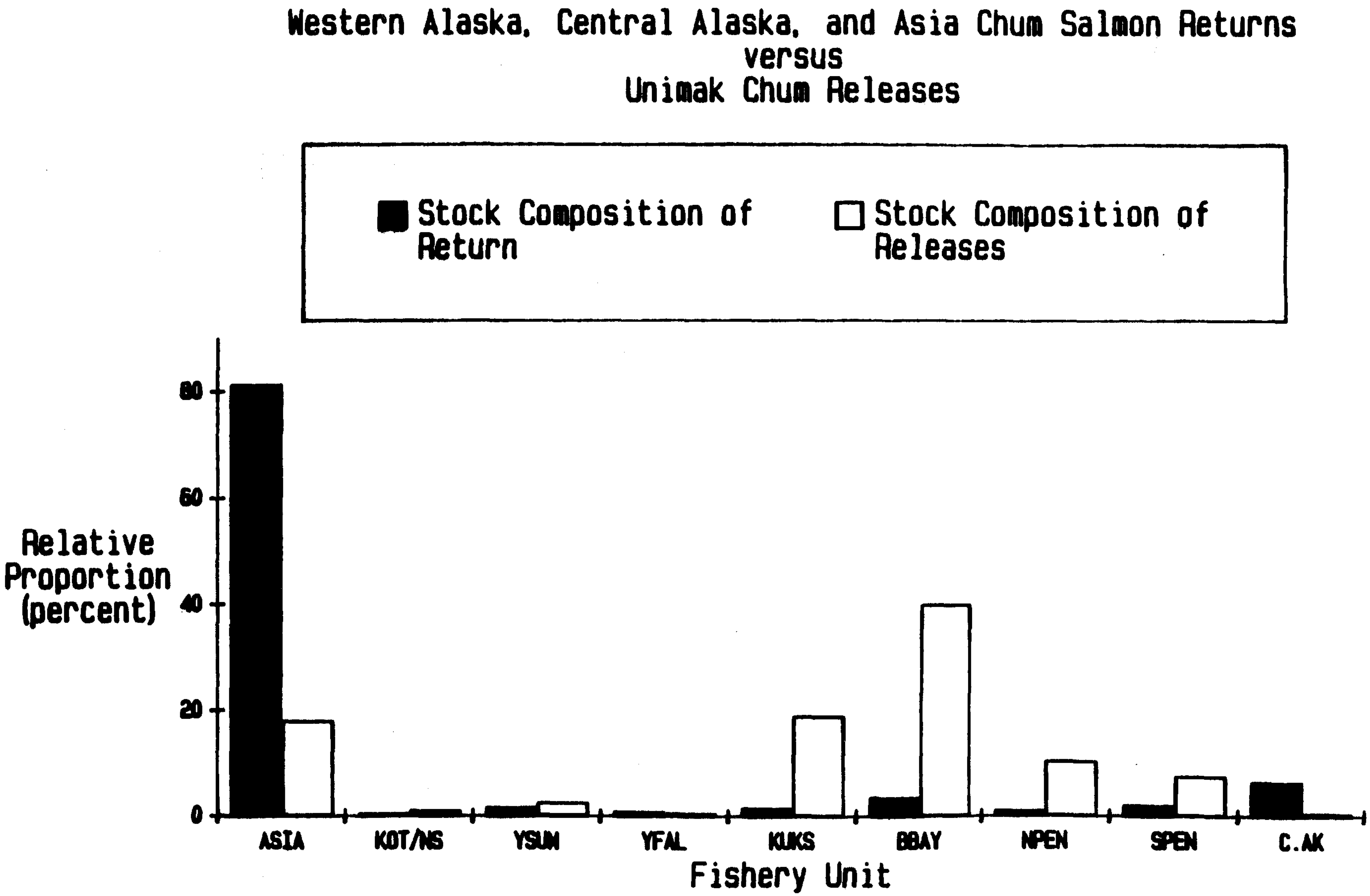


Figure 38. Stock composition (% of total return) of western and central Alaska chum returns versus stock composition (% of surviving releases less estimated Asian stocks) of Unimak releases of chum salmon, for various fishery units. Figure taken from Eggers et al. (1989).

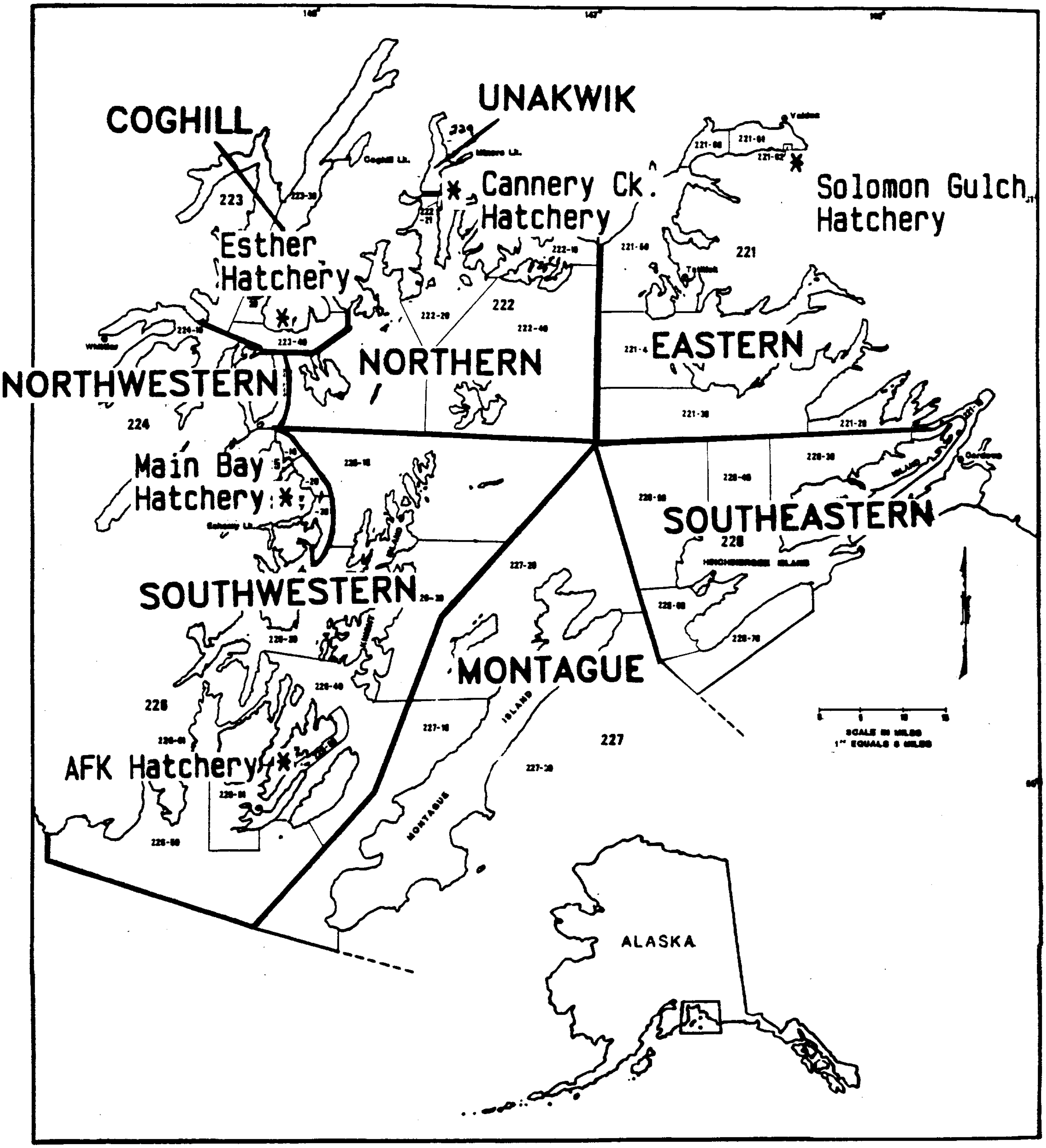
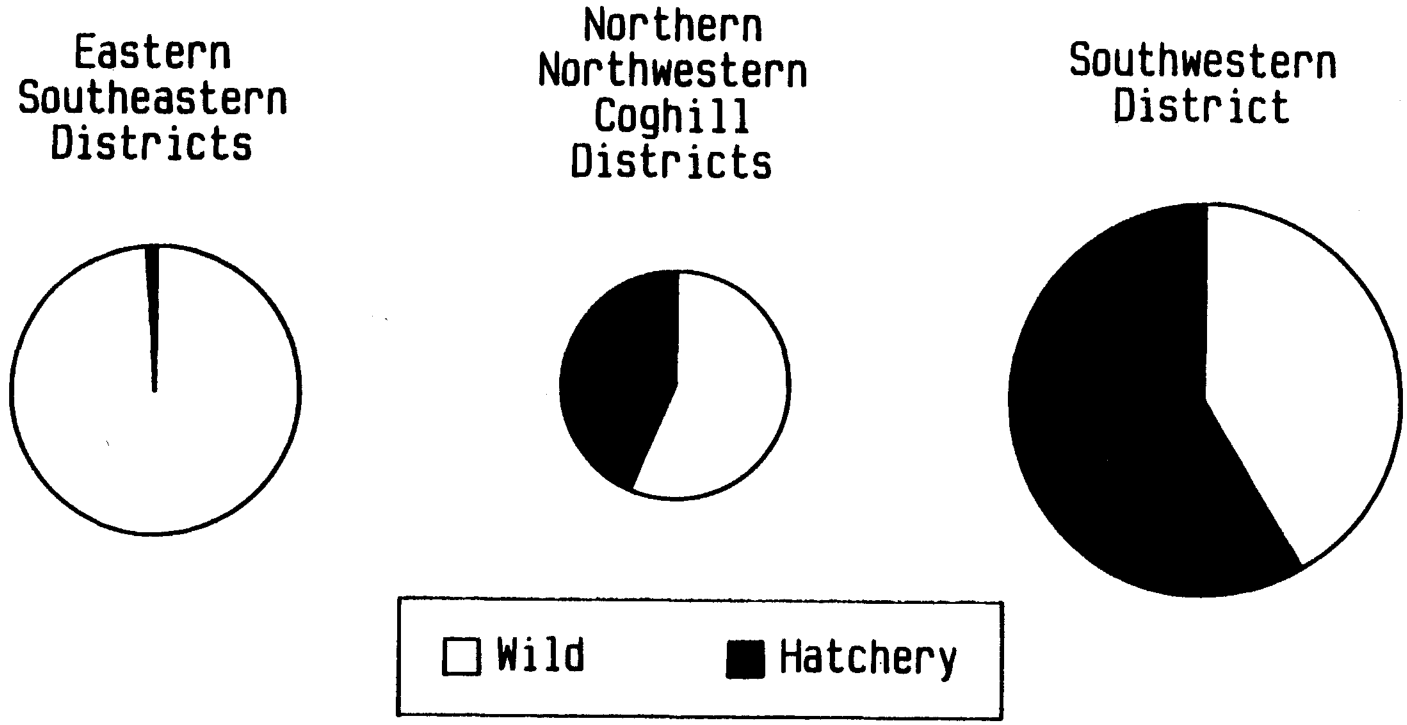


Figure 39. The Prince William Sound area with fishing district boundary lines and locations of hatchery facilities.



1987 Prince William Sound Catch of Pink Salmon

Hatchery	13.7	
Wild Stocks	12.4	
Total	26.1	million fish

Figure 40. Hatchery and wild stock composition of 1987 Prince William Sound pink salmon catches for Eastern and Southeastern Districts; Northern, Northwestern, and Coghill Districts; and Southwestern District.